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REPORTS

OF THE

COMMISSIONERS OF THE UNITED STATES

TO THE

INTERNATIONAL EXHIBITION

HELD AT

VIENNA, 1873.

PUBLISHED UNDER DIRECTION OF THE SECRETARY OF STATE
BY AUTHORITY OF CONGRESS.

EDITED BY

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A.

MACHINERY AND MANUFACTURES.

R. H. THURSTON.

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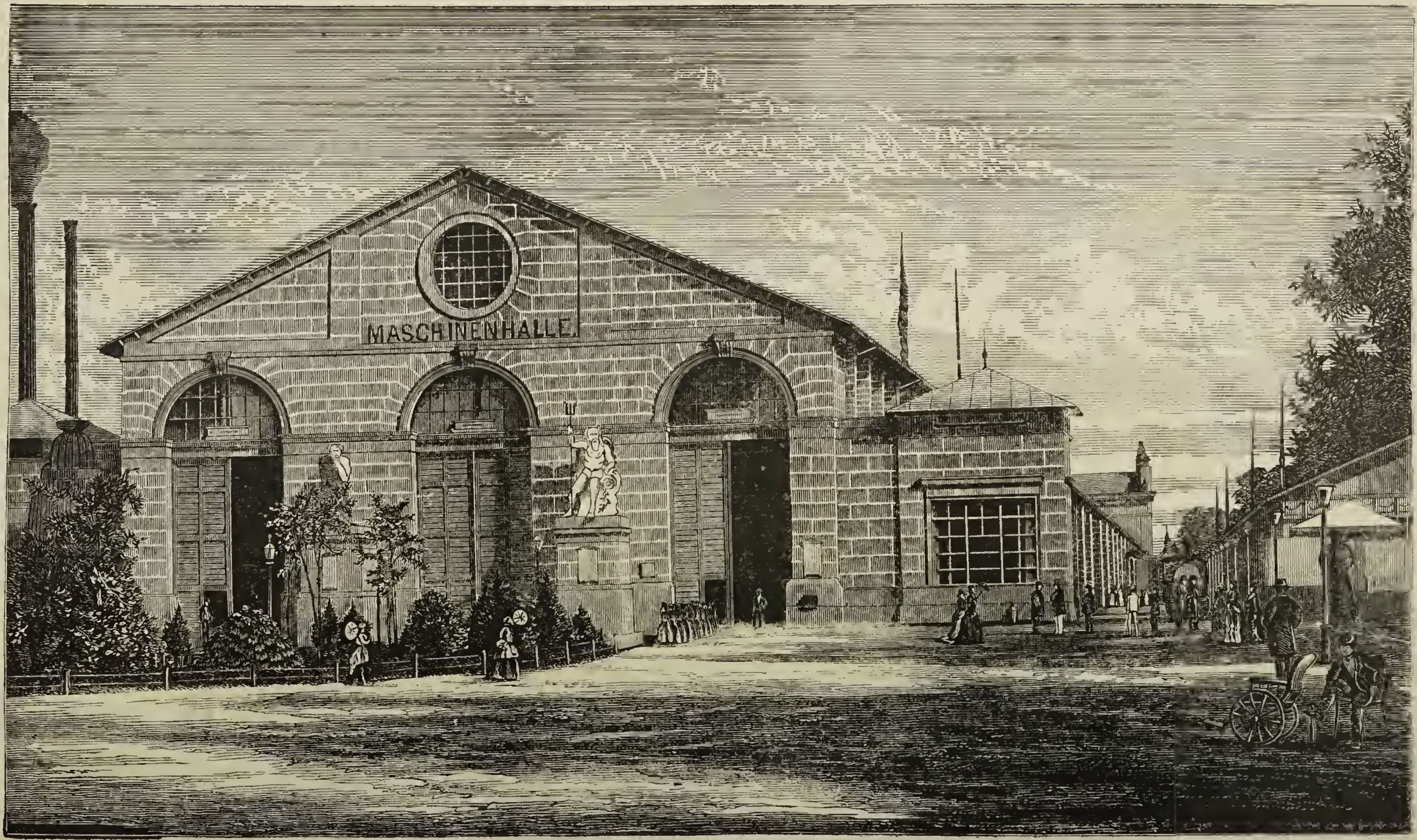

Machinery Hall.

VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON

MACHINERY AND MANUFACTURES,

WITH

AN ACCOUNT OF EUROPEAN MANUFACTURING DISTRICTS.

BY

ROBERT H. THURSTON, A. M., C. E.,

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SCIENTIFIC COMMISSION OF THE UNITED STATES.

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REPORT

ON

MACHINERY AND MANUFACTURES.

PART I.

MACHINERY EXHIBITED AT VIENNA, 1873.

[If the history of the progress of the mechanical arts be interesting, still more so, doubtless, would be the exhibition of their present state and a full display of the extent to which they are now carried. The slightest glance must convince us that mechanical power and mechanical skill, as they are now exhibited in Europe and America, mark an epoch in human history worthy of all admiration. Machinery has been made to perform what has formerly been the toil of human hands to an extent that astonishes the most sanguine, with a degree of power to which no number of human arms is equal, and with such precision and exactness as almost to suggest the notion of reason and intelligence in the machines themselves. Every natural agency is put unrelentingly to the task. The winds work, the waters work, the elasticity of metals works; gravity is solicited into a thousand new forms of action; levers are multiplied upon levers; wheels revolve on the periphery of other wheels; the saw and the plane are tortured into an accommodation to new uses; and, last of all, with inimitable power, and "with whirlwind sound," comes the potent agency of steam. In comparison with the past, what centuries of improvement has this single agent comprised in the short compass of fifty years! Everywhere practicable, everywhere efficient, it has an arm a thousand times stronger than that of Hercules, and to which human ingenuity is capable of fitting a thousand times as many hands as belonged to Briareus. Steam is found in triumphant operation on the seas; and, under the influence of its strong propulsion, the gallant ship,

Against the wind, against the tide,
Still steadies with an upright keel.

It is on the rivers, and the boatman may repose on his oars; it is on highways, and exerts itself along the courses of land-conveyance; it is at the bottom of mines, a thousand feet below the earth's surface; it is in the mill, and in the workshops of the trades. It rows, it pumps, it excavates, it carries, it draws, it lifts, it hammers, it spins, it weaves, it prints. It seems to say to men, at least to the class of artisans, "Leave off your manual labor; give over your bodily toil; bestow but your skill and reason to the directing of my power, and I will bear the toil, with no muscle to grow weary, no nerve to relax, no breast to feel faintness!" What further improvement may still be made in the use of this astonishing power it is impossible to know, and it were vain to conjecture. What we do know is, that it has most essentially altered the face of affairs, and that no visible limit yet appears beyond which its progress is seen to be impossible.—DANIEL WEBSTER.]

REPORT ON MACHINERY AND MANUFACTURES.

PART I.

REPORT ON MACHINERY EXHIBITED AT VIENNA, 1873.

INTRODUCTION.

Success of the Exhibition; Machinery-hall; Scope of the report; Character of the exhibit as a whole; The international jury; Defects of the jury-system; Organization of the jury; Methods of jury-work; Assignment of jurors from the United States; Distribution of awards; Periods of session; Statistics of awards; Faults of management on the part of exhibitors; Causes of success of exhibitors from the United States; The United States section; The Exhibition as a whole; Continental nations as copyists.

1. The Vienna International Exhibition of 1873 was probably the most completely satisfactory exhibition of industrial processes, apparatus, and products that has yet been attempted.

The general administration, the organization of the Exhibition, and the manner in which it was conducted throughout the period of its existence were admirable. The defects of arrangement and errors in management and the accidents which sometimes occurred to break in upon the absolute smoothness with which the machinery of administration and management usually ran were much fewer and less important than might have been expected in such a gigantic and unexampled enterprise.

2. Among the many interesting departments of the Exhibition, none were more interesting to the general public and none assumed greater importance in the eye of the political economist and the statesman than that contained within the "*Maschinen Halle.*" (Frontispiece.)

Within this great building (which had a floor-space of 40,000 square meters, or nearly ten acres) were collected many thousands of exhibits, embracing every known variety of machinery. The building was traversed, as shown in the engravings illustrating this report, from end to end by two aisles, dividing the machinery in motion, which was distributed along the middle line of the building, from that which did not require motive-power, and which was arranged on either side.

The visitor walking through the building found on either side, for a distance of a half-mile, an unbroken mass of machinery, of every class, of all degrees of magnitude, and of every conceivable variety of style, material, workmanship, and finish. The difficulty of making a complete and satisfactory examination of all of these devices, many of which would demand the attention for hours, or even days, if the visitor were attempting to acquire a thorough knowledge of details, may readily be conceived. The utmost patience, the most complete knowledge of engineering, and steady application throughout the whole period of the exhibition would scarcely suffice. To examine the 5,000 exhibits of Group XIII alone, giving five minutes to each, would require more than forty days' work of ten hours each. But a single "exhibit" was frequently composed of several, or even of many, separate machines, either of which would afford full compensation for hours expended in study. This was the case with the majority of the exhibits in the United States section, and with many others in every department.

It would, therefore, be quite hopeless to attempt to make a report upon this class of exhibits absolutely complete; and if it can be made even tolerably satisfactory, the reporter may consider himself fortunate.

3. The report here given is confined to the department to which the writer was assigned, as a member of the International Jury—to Group XIII, Machinery.

In this group are comprehended many classes of machinery with which, either in consequence of their infrequent use in America or of a complexity which demanded such study as time did not permit, the writer was not sufficiently familiar to criticise confidently. Other classes are of little interest to the manufacturers and the workingmen of the United States, in consequence of the fact that they have already learned to excel foreign makers to such a degree that to describe them would be a simple repetition of a story long ago familiar.

The endeavor has been to condense within the following pages as much information as could properly be gathered into such a report, omitting as little as possible that might be expected to prove useful to its readers, and accepting information, supplementary of the observation of the writer, from whatever source it could be obtained.

Such a report must necessarily partake somewhat both of the character of a treatise upon industrial materials, apparatus, and processes, and of that of a descriptive catalogue of exhibits. It has been the intention of the writer to criticise impartially and to suggest, where it appeared proper, directions in which to look for further progress. The work has been one of difficulty, but of exceeding interest; arduous, but very instructive.

4. The collection of machinery, as a whole, was somewhat unsymmetrical and incomplete. Many classes of machines were entirely unrepresented, and others were exhibited in numbers quite disproportionate to their importance.

The unfortunate patent-systems of Europe prevented many foreign makers from appearing where they considered themselves liable to the piracy of their most valuable devices. The somewhat illiberal spirit which prevails to a greater extent in Europe than in the United States, and which induces manufacturers to avoid giving more publicity than they are compelled to less important matters of detail, also had the effect of keeping away many well-known European manufacturers. But in spite of this, the collection formed a magnificent encyclopedia of mechanism.

The official examination and the award of prizes throughout the exhibition were intrusted to an International Jury.

5. THE INTERNATIONAL JURY consisted of over six hundred members, selected by the governments of the countries exhibiting at Vienna. It was divided into twenty-six "groups," to each of which was assigned a department of the Exhibition for examination.

The members of the jury were appointed to those groups in which they were supposed to be fitted to act most intelligently.

6. Group XIII comprehended all machinery and means of transport. The exhibits in this group were 4,694 in number, and were distributed in four sections, exclusive of agricultural machinery, which was assigned to Group-jury II. It was to this group that the writer was assigned.

These exhibits were classified as follows:

Number of exhibits in Group XIII, exclusive of agricultural machinery.

Sections.	Russia.	Hungary.	Austria.	Germany.	France.	Switzerland.	England.	United States.	Belgium.	Italy.	Sweden and Norway.	Denmark.	Holland.	Totals.	
I.															
Prime movers	14	7	98	210	55	34	20	5	6	2	8	1	7		467
II.															
Metal-working machinery	6	3	61	180	30	17	39	34	21	12	......	....	....	403	3, 432
Wood-working machinery	1	3	83	50	26	...	60	24	....	...	31	....	....	278	
Textile machinery	....	3	293	300	54	65	65	3	45	...	......	....	...	828	
Various kinds, unclassified	18	64	518	330	83	38	266	450	97	8	......	40	11	1, 923	
III.															
Means of transport	58	75	152	60	18	4	22	22	120	3	3	1	1		539
IV.															
Street-railroads	23	43	92	52	10	6	24	1	..	....	1	4	....		526
Totals	120	198	1, 297	1, 182	276	164	496	539	289	25	43	46	19		4, 694

7. The great defect of the jury-system of examination and report, as adopted at these international exhibitions, is one which is evidently inherent, and one which it is probably impossible to completely remedy.

The large number of exhibits, the comparatively small number of jurors, and the limited time allowed, forbid that thorough examination and careful comparison which should always precede the formation of an opinion and the framing of a report. In many cases only an actual and careful test of the competing apparatus can give a really reliable basis for discrimination. The steam-engine which received the highest honor at Vienna was quite well designed and very well constructed; yet there were many others, apparently at least, equally as well designed and quite as well built. The jury could not, however, find time to make a test-trial of each, but were compelled to rely upon appearances, and, perhaps, to give some weight to the reputation of the firm. There seems to be no remedy for this defect; it is, however, a very serious one.

8. The jury to which was assigned the examination of Group XIII was composed as follows:

GROUP XIII.

PRESIDENT.

Herr Wilhelm Ritter von Engerth, of Vienna, Austria.

VICE-PRESIDENTS.

Herr Dr. C. Karzmarsch, director of the Polytechnic School of Hanover, German Empire.

Dr. J. Anderson, machinery department, Woolwich, Great Britain.

JURORS.

Herr C. A. Angström, professor in Technical School at Stockholm, Sweden.

M. Belpaire, inspector-general of railways, Belgium.

Herr Dr. Böttcher, director of the Industrial School of Chemnitz, German Empire.

Signor Colombo Cavaliere, professor, Giuseppe, Italy.

Herr Professor G. Delabar, of St. Gallen, Switzerland.

M. Ehrler, France.

Herr Rudolph Grimus, Ritter von Grimburg, professor in the Technical Academy, Vienna, Austria.

Herr Dr. E. Hartig, professor at Dresden Polytechnic School, German Empire.

Herr Gustav Herrmann, professor in Technical School at Aachen, German Empire.

G. V. Holmes, esq., Great Britain.

Joseph E. Holmes, esq., New York, United States of America.

Herr Carl Jenny, professor in Technical School at Vienna, Austria.

Herr von Kessler, director of the *Maschinenfabrik Esslingen*, German Empire.

Herr Johann Lindemann, captain, Denmark.

Herr Jacob Lohner, of Vienna, Austria.

Signor Padula, professor in Engineering School of Naples, Italy.

Herr Emerich Pekar, Hungary.

Herr Carl Pfaff, of Ottakring, Vienna, Austria.

Herr F. Reuleaux, director of the Polytechnic School at Berlin, German Empire.

Mon. H. Schneider, of Creuzot, France.

C. W. Siemens, esq., F. R. S., London, Great Britain.

Herr G. Sigl, of Vienna, Austria.

Prof. R. H. Thurston, of the Stevens Institute of Technology, New Jersey, United States of America.

Mon. H. Tresca, subdirector of the *Conservatoire des Arts et Métiers*, Paris, France.

Herr Stephan Verderber, chief engineer in the Hungarian board of trade, Pesth, Hungary.

M. J. Vichnegradski, professor in Industrial Academy, St. Petersburg, Russia.

Herr A. Wöhler, of Berlin, German Empire.

SUPPLEMENTARY JURORS.

Herr Professor Autenheimer, of Basel, Switzerland.

M. J. Beco, ingénieur, Belgium.

Herr Max Bielek, professor in Pesth, Hungary.

Signor Chizzolini, Italy.

M. Desouches, France.

Herr Emil Herrmann, Hungary.

M. V. Kirpitscheff, professor in Technical School of St. Petersburg, Russia.

M. Henri Mathieu, France.

EXPERT.

M. Kindt, Belgium.

9. The majority of these names are familiar to engineers as those of men who are distinguished either in the practice of the profession or for their scientific attainments. The working of the jury, as a whole, indicated a fortunate combination of the two classes which composed it.

The jury assembled on Saturday, June 14, and, after organization, several days were occupied in the arrangement of the plan of operations and in discussing the general methods to be pursued.

10. The group-jury was finally divided into sections as follows:

SECTION 1.—Prime movers.

SECTION 2.—Machines for working metal, wood, and textile materials.

SECTION 3.—Means of transport in general.

SECTION 4.—Street-transportation.

Section 2, containing nearly three-fourths of all the exhibits in Group XIII, was further separated into two subdivisions:

Class 1.—Wood and metal working machinery.

Class 2.—Textile machinery, including sewing-machinery.

11. In the absence of his colleague on Group XIII, who had not then reported, the writer attached himself to Class 1, Section 2, in which

were interested the larger number of exhibitors from the United States, and which included our most important interests. The second member was assigned to Class 2 of the same section, as that was considered next in importance. The remaining sections were unavoidably left without representatives from the United States. On the whole, this fact probably did not injuriously affect the standing of the comparatively small number of exhibitors interested in those sections.

12. In some instance the awards proposed for our exhibitors were evidently not such as were deserved; but a simple representation of the case at a session of the group-jury was usually sufficient to secure reconsideration. Awards that were deemed satisfactory were, in most instances, allowed after a more complete investigation had been made.

We have to regret that in two or three cases the lack of familiarity of members of the jury with the conditions under which our industrial enterprises are conducted, or their peculiar views of business principles, or of manufacturing processes as derived from an experience differing vastly from that of the American mechanic, prevented exhibitors from obtaining the high awards to which they were properly entitled. It is fortunate, however, that in these cases the exhibitors had already attained a reputation at home which rendered them perfectly safe against the false inference which might have been based upon their non-success had they been less well known.

13. The sessions of the sectional juries were held daily, and occupied all available time up to July 18. During this period, the jury met every morning at 9 o'clock, and spent the day examining exhibited machinery and in comparing their claims to distinction. As awards were determined upon, they were reported to the group-jury for confirmation.

14. On the 9th day of July the writer was detailed by the Commissioner-general to represent the executive commission at the international field-trial of agricultural implements and machinery at Siebenbrunn. A detailed account of this trial, which resulted in securing an *Ehren Diplom* for one American machine, and medals for several other mowers and reapers from the United States, will properly be given in the report of the jury. The trial occupied the entire day, and was very satisfactory, so far as it went. The competition was, in fact, one between exhibitors from the United States. The English exhibitors had withdrawn entirely, and the only foreign-built machines which entered the field were too heavy and too inconveniently arranged to have a chance of success.

The best of the European machines was that of Hofherr, of Vienna, a substantial and well-built machine, which did good work.

The trial was very incomplete, as no dynamometric determinations of direct traction or side-draught were made. No special examination was made of the condition of machines before and after their work was done, and no means were adopted to ascertain whether heated journals or choked knives and machinery were more difficult of prevention in one machine than in another. The character of the work done, the time occupied, and the general construction of each machine were the bases of awards.

15. The result of the work of the jury of Group XIII will be seen on examining the report of the Commissioner-general and the official list of awards published by the Austrian authorities. Awards were distributed amongst various countries as follows:

Country.	Diplomas of honor.	Medals of progress.	Medals of merit.	Diplomas.	Total.
America	2	30	23	18	73
England	5	39	43	41	128
France	6	41	37	42	126
Switzerland	3	14	19	12	48
Denmark	1	2	4	5	12
Sweden	1	2	3	1	7
Belgium	2	9	11	15	37
Germany	10	83	169	79	341
Austria	8	49	84	104	245
Hungary	1	10	10	24	45
Russia	1	7	16	13	37
Total	40	286	419	354	1,099

16. Comparing the awards made to the exhibitors from the United States with those accorded to those from other countries, there will be noticed a marked difference between the proportions of the number of medals of progress to that of medals of merit in Group XIII.

There were a larger number of the former given to the United States in this group than of the latter. This proportion was reversed with all other nations. American exhibitors received thirty medals of progress and twenty-three medals of merit. The former award was intended to be given to exhibitors who had given evidence of marked improvement, effected since the year 1867, the date of the last international exhibition. It is to be taken as a reward, not only of intrinsic merit, but of an actual advance, within this period, effected in a device which was then considered particularly meritorious.

17. Of the total of nine diplomas of honor granted in all groups to exhibitors from the United States, five were awarded to national, state, or municipal institutions and four to individual exhibitors.

The diploma of honor was the highest honor given at Vienna. It was intended to confer peculiar distinction upon those who had aided most effectively by intellectual, industrial, or material contributions, the advancement of civilization. This highest award was made only by the council of presidents of juries, on the recommendation of a group-jury. Of the four diplomas of honor accorded to private exhibitors from the United States, three were given to exhibitors of important classes of machinery, viz: To George H. Corliss, for the Corliss steam-engine; to William Sellers & Co., for machine-tools and metallurgical machinery, and to W. A. Wood, for mowing-machines.

There was no opposition to the proposal to confer this high honor upon these exhibitors, and the recommendation was made unanimously. An apparent legal impediment in the case of the first-named was found in the fact that the recipient of the award did not formally exhibit his machine. This difficulty was met by the statement that, notwithstanding the fact that he did not appear as exhibitor, a large proportion of the steam-engines entered having been copied from his designs, he was really represented in every section of the Exhibition and by the engine-builders of every manufacturing nation. His name was familiar to every member of the jury, and, with the majority, his was the only name which had become known in connection with the recent improvement of the steam-engine in the United States. No real opposition appeared to this nomination, which was actively sustained by the ablest members of the jury.

18. On the whole, the awards made to the exhibitors in the United States section were very judiciously distributed, and the few errors which an inspection of the official list may reveal are due principally to the unfamliarity of the majority of members of the jury with the advanced methods and the fine distinctions to which the American mechanic is accustomed. Consequently, the difficulties met by our exhibitors in the endeavor to present fully the merits of their devices were sometimes serious.

American exhibitors were extremely careless, also, in preparing proper circulars for the use of the jury. Exhibitors of other nations usually had circulars printed in the English, French, and German languages, in which their exhibits were carefully described, and, when necessary, the descriptive text was illustrated by neatly-made engravings, showing every important detail plainly, and in which all points of difference between it and other devices of the same class were distinctly pointed out, and the consequent advantages stated, the points taken being sustained by evidence. Some of these exhibitors even published books of considerable size, and of great intrinsic value.

In many cases, the exhibits in the United States section were unaccompanied by even an ordinary business circular. It was very generally the fact that no representative of the exhibitor had accompanied them to Vienna, and it became necessary for the members of the executive commission and its employés, and for members of the jury, to devote an amount of time and attention to these matters which could with difficulty be given them at a time when the pressure of official duties was in itself a serious burden upon both the physical and the mental powers.

19. The success of exhibitors in the United States section is, therefore, all things considered, somewhat remarkable, and it is an evidence of the high reputation acquired by American mechanics abroad, as well as of the actual merit of their productions. It could hardly have been possible for them, in the absence of proper representatives, to have

secured so careful an examination of their contributions as was given them by the overworked jury, solicited as its members were, on all sides, by the active agents of competitors, had not the members already learned to look to the United States for very much of all that is novel and ingenious in modern mechanism.

20. During the attendance of the writer at the Exhibition, his time was too closely occupied with jury-work to permit as complete an examination as it was desired to make of the specimens of engineering skill there shown outside of the group to which his attention was officially called.

Of the section assigned to the United States, an account has already been given in a report made while in Vienna, and which was forwarded by the United States minister. It is only necessary here to repeat that that department was sadly deficient in the variety of its exhibits and in the extent of its display. The most creditable portion of the section was that in the machinery-hall, where a larger number of original inventions, ingenious machines, and "new and useful" devices were exhibited than could be found elsewhere.

The accompanying plan and the illustrations distributed through this report, which were made from photographs, exhibit better than could any verbal description the arrangement and appearance of the United States section, and of other parts of Machinery-Hall.

21. The exhibition, as a whole, was remarkably deficient in novelties in apparatus or in processes, and an American mechanic could not fail to be surprised by the evident lack of originality among European constructors, and to be disappointed in his expectation of finding, at an "international exhibition," in which the whole civilized world was represented, so little that was new and such slight evidence of progress in the industrial arts since the Paris Exposition of 1867.

In comparing the sections assigned to the various nations which were represented in Machinery-Hall, it became evident on the most cursory examination that the truly novel was almost invariably found in the sections of Great Britain and the United States.

Great Britain greatly excelled all other nations in the variety of machinery exhibited, in substantial construction, and in the effectiveness of her standard machinery. The display made by citizens of the United States was, though limited in extent, the richest in new forms of apparatus, and contained by far the most striking examples of the special adaptation of machines to peculiar varieties of work, and of what is commonly designated as "labor-saving" machinery.

22. All other nations, as a rule, simply presented copies of British and American machines. These were frequently announced as such, seemingly to secure confidence in their value. Corliss engines, and tools marked "*Système Sellers*," or copied from Browne & Sharpe, Pratt & Whitney, and others of our well-known mechanics, were frequently met with.

When a deviation from standards had been attempted, it was very commonly unsuccessful, both in design and execution. The French firms of Ducommun & Co., of Mulhouse, and Schneider, of Creuzot, were marked exceptions to this rule, as were also the Cockerill Iron Works, of Seraing, Belgium, and Krupp, of Essen, Prussia. All of these establishments turned out work that was remarkable for its excellence of material and finish. They exhibited less originality in design than their British and American competitors, but in standard designs they were almost unexcelled.

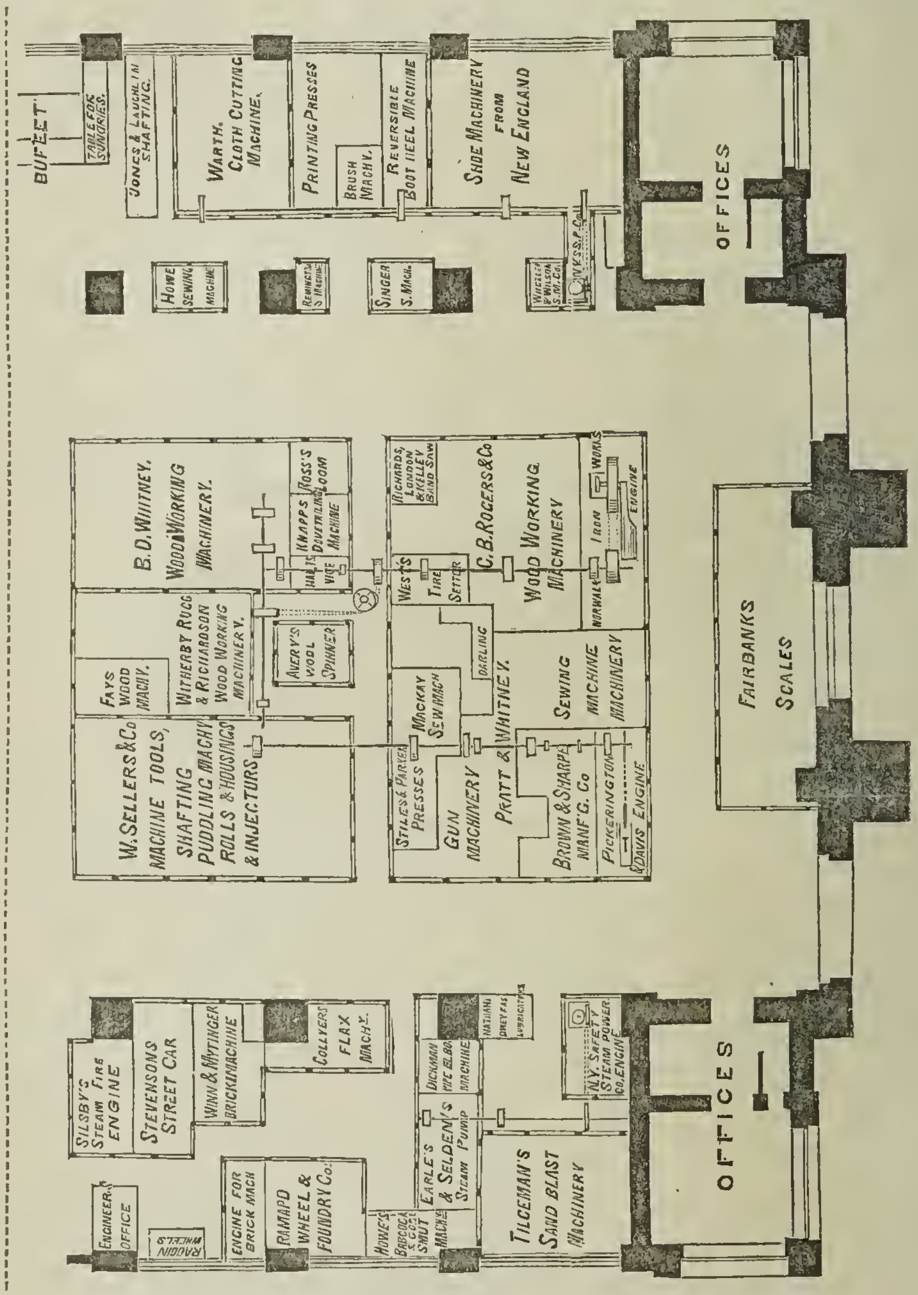
BUFFET
TABLE FOR SUNDRIES
JONES & LAUCHLIN SHAFTING
WARTH. CLOTH CUTTING MACHINE
PRINTING PRESSES
BRUSH MACHY.
REVERSIBLE BOOT HEEL MACHINE
SHOE MACHINERY FROM NEW ENGLAND
OFFICES
HOWE SEWING MACHINE
REMINGTON S. MACHINE
SINGER S. MACH.
WHEELER & WILSON S.M.Co.
B.D. WHITNEY. WOOD WORKING MACHINERY.
ROSS'S LOOM
KNAPPS DOVETAILING MACHINE
HALL'S VICE
RICHARDS, LONDON & KELLEY BAND SAW
C.B. ROGERS & Co WOOD WORKING MACHINERY
IRON WORKS
ENGINE
NORWALK
WEST'S
TIRE SETTER
FAIRBANKS SCALES
WITHERBY RUGG & RICHARDSON WOOD WORKING MACHINERY.
FAYS WOOD MACHY.
AVERY'S WOOL SPINNER
DARLING
MACKAY SEW MACH.
SEWING MACHINE MACHINERY
W. SELLERS & Co MACHINE TOOLS, SHAFTING PUDDLING MACHY ROLLS & HOUSINGS & INJECTORS
STILES & PARKER PRESSES
GUN MACHINERY
PRATT & WHITNEY
BROWN & SHARPE MANF'G. Co
PICKERING GOV.
DAVIS ENGINE
SILSBY'S STEAM FIRE ENGINE
STEVENSONS STREET CAR
WINN & MYTINGER BRICK MACHINE
COLLYERS FLAX MACHY.
DICKMAN PIPE ELBOW MACHINE
NATHAN & DREYFUS LUBRICATORS
N.Y. SAFETY STEAM POWER Co. ENGINE
EARLE'S & SELDEN'S STEAM PUMP
TILCEMAN'S SAND BLAST MACHINERY
OFFICES
ENGINEER'S OFFICE
ENGINE FOR BRICK MACH
RAMAPO WHEEL & FOUNDRY Co.
HOWE'S

FIG. 1.—United States Section, Machinery-Hall. (Plan.)

Several Austrian firms, notably that of Pfaff, Fernau & Co., of Vienna, in the manufacture of machinery, and George Sigl, in locomotive-building, did excellent work.

Borsig, of Berlin; Schmaltz of Saxony, and Zimmermann, exhibited well-made machines.

The Zurich builders attracted attention as the exhibitors of work of more than usual excellence, and also as having produced some excellent and partly original designs. They were evidently far in advance of average European practice.

The observations made by the writer when studying in detail the class of exhibits with which he was particularly conversant, and in which he was, by habits and pursuits, most interested, are given in the succeeding Report on Special Exhibits; while those made upon the general tour of Europe, after the completion of the work at Vienna, follow in a section devoted to European manufacturing establishments and technical schools.

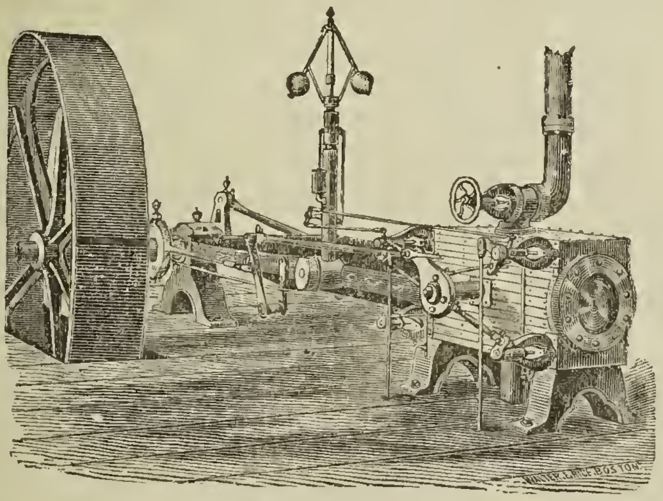

FIG. 2.—The Corliss engine.

Vienna Exhibition 1873. Machinery etc.

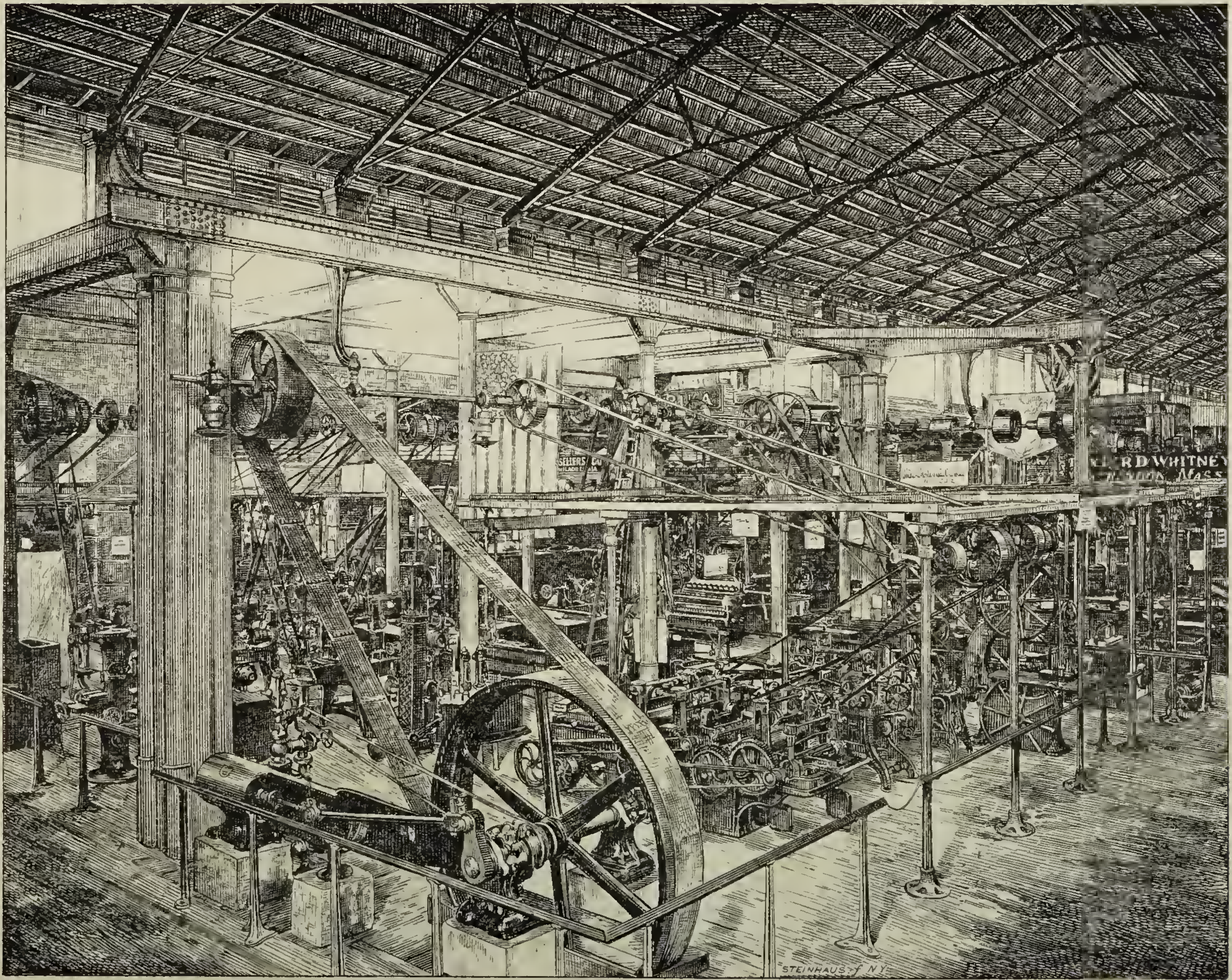

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Fig. 3.

MACHINERY AND TOOLS.

INTRODUCTION.

METHOD OF STUDY; CHARACTERISTICS OF NATIONAL EXHIBITS.

23. In so vast a collection as that which crowded the great "*Maschinen Halle*," and its several annexes, the visitor could only thoroughly inspect and critically compare the exhibits by an expenditure of time and labor which was commensurate with its extent.

In making this examination during the several weeks given to it, the plan was adopted of taking up one class after another, and seeking out the representative exhibits in each section, studying their general plans of construction, peculiarities of design, and the arrangement and proportions of details, and after completing this work in the collection contributed by one nation, passing on to the next, and finally making a general comparison of the distinguishing features of each and of the character of material and workmanship.

24. Each nation was usually found to excel in some special department of industry, but the difference between the several continental nations, and between them all and their Anglo-Saxon competitors was, as will be seen, always plainly observable, and sometimes very striking. The usual characteristics of the South Europeans were elegance and lightness of form, with beauty of external finish. The North Europeans appeared to best advantage where simplicity of form, strength of parts, and general adaptation to useful purposes, demanding no display of fine art, were requisites.

The British and Americans both excelled in originality, the former displaying the highest excellence of workmanship and promise of greatest durability, and the latter the most remarkable ingenuity and capacity for making the most of their resources.

CHAPTER I.

STATIONARY STEAM-ENGINES.

State of European practice; Historical outline of modern progress; Limits of economic gain by expansion; Present position of European builders; Comparison of practice of various nations; Conditions of efficiency; Directions for the attainment of economy; Engine of Socin & Wick; Engine of Sulzer Frères; Trial of the Sulzer engine; Plain slide-valve engines; Engine of the Norwalk Iron Company; Norwalk Safety Steam-Power Company; Tangye Brothers' engine; Compound engines of W. & J. Galloway, of Schneider & Co.; The Ehrhardt-Dingler engine; The Porter-Allen engine; The Pickering engine; Brotherhood & Hardingham's three-cylinder engines; Siemens's engine; Review of the whole field; Dimensions of exhibited engines; Influence of American designs on European practice.

25. Recent Progress.—The ninety stationary steam-engines of the Exhibition were carefully examined; but the writer regrets to be compelled to state that there was very little to be found at Vienna in this class that was really new and valuable.

European practice is evidently passing through very nearly such a series of changes as have been noted in our own country by every engineer who can trace them back twenty years.

26. The value of high pressures and considerable expansion was recognized as long ago as in the early part of the present century, and Watt, by combining skilfully the several principal organs of the steam-engine, gave it very nearly the shape which it has to-day. The compound engine, even, was invented by contemporaries of Watt, and the only important modifications since his time have occurred in details. The introduction of the "drop cut-off," the attachment of the governor to the expansion-apparatus in such a manner as to determine the degree of expansion, the improvement of proportions, the introduction of higher steam and greater expansion, the improvement of the marine engine by the adoption of surface-condensation, in addition to these other changes, and the introduction of the double-cylinder engine, after the elevation of steam-pressure and increase of expansion had gone so far as to justify its use, are the changes which have taken place during this century. A quarter of a century ago it began to be generally understood that expansion of steam produced an economical effect, and mechanics and inventors vied with each other in the effort to obtain a form of valve-gear which should secure the immense economy which an abstract consideration of the expansion of gases according to Marriotte's law would seem to promise. The counteracting phenomena of internal condensation and re-evaporation, ot the losses of heat externally and internally,

and of the effect of defective vacuum, defective distribution of steam, and of back pressure, were either unobserved or were entirely overlooked.

27. It was many years, therefore, before our engine-builders became convinced that no improvement upon existing forms of expansion-gear could secure even an approximation to theoretical efficiency. Occasionally an engineer of unusual intelligence and of exceptional power of observation found this to be the fact.

Mr. Francis B. Stevens, by a careful collation of indicator-cards, constructed more than twenty years ago the formula

$$p = \mathrm{P}\frac{1 + \mathrm{A}\ \mathrm{hyp}\ \log e}{e} - \mathrm{B} - \mathrm{CP}^*$$

in which p represented the mean pressure, P the boiler-pressure, e the expansion, A, B, C, constants determined by observation of actual performance of engines. This formula is made the basis of another, which gives the probable consumption of fuel at any degree of expansion and at any given pressure. By this latter equation a series of minimum rules was worked out by its author, which gave what would now be recognized by an experienced engineer as very correctly representing the limit of economical expansive working. The available energy of steam rises as pressure and temperature increase, in consequence of the widening of the range of temperature through which expansion occurs, to an extent which somewhat increases the economical range of expansion beyond the limit as thus deduced from extra-thermal considerations. This rise is not rapid, however, and Mr. Stevens's figures are very probably closely accurate.

28. The fact thus learned, that the benefit of expansive working has a limit which is very soon reached in ordinary practice, was not then, and has only recently become, generally known among our steam-engine builders, and for many years there continued the keenest competition between makers of rival forms of expansion-gear, and inventors were continually endeavoring to produce something which should far excel any previously-existing device.

This phase of the process of steam-engine improvement seems to have been just reached in Europe, and the general recognition of the value of a good detachable valve-gear, with the governor so attached as to determine the point of cut-off, has caused a rivalry among European builders, in the effort to produce the best valve-motion, which has led to the introduction of just such a variety of devices—usually crude, unmechanical, and complicated—as we have been so familiar with in the United States. In Europe, as in the United States, efforts to "improve" standard devices have usually resulted in injuring their efficiency and in simply adding to the first cost and running expense of the engines, without securing a marked increase in economy in the consumption of steam.

Since European practice may be regarded as having grown out of, and as having progressed during late years by imitation of, American practice in the manufacture of first-class stationary engines, it is unnecessary to give here further description of any of this class of machinery.

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* $\mathrm{A} = 2.3$; $\mathrm{B} = 5$; $\mathrm{C} = 0.06$.

29. In the production of the best engines, several nations have exhibited great skill in workmanship, and have made use of excellent material. The British stand at the head of European nations, and side by side with the manufacturers of the United States. The Belgians, the French, and the Swiss are following the English-speaking nations very closely, and the Germans and Austrians are rapidly closing up the wide space which so recently separated them from the former.

In one form of stationary steam-engines the English excel all countries, not excepting the United States. This is the small horizontal slide-valve engine, with independent slide cut-off riding on the back of the main valve—a combination generally known among engineers as the Meyer system of valve-gear. This form of steam-engine is a very excellent and effective machine, and does excellent work when properly proportioned to yield the required amount of power. It is well adapted to an expansion of from four to five times. Its disadvantages are the difficulty which it presents in the attachment of the regulator to determine the point of cut-off by the heavy work which it throws upon the governor when attached, and the rather inflexible character of the device as an expansive valve-gear. The best example of this class of engine had neat heavy bed-plates, well-designed cylinders and details, smooth-working valve-gear, the expansion-valve adjusting by a right and left hand screw, and regulation secured by the attachment of the governor to the throttle-valve.

A considerable number of compound stationary engines were exhibited in various departments. The larger proportion were neither neat in design nor well proportioned. The valve-gear was frequently very awkward in general arrangement, and not at all satisfactory in any respect.

30. CONDITIONS OF EFFICIENCY.—The principles and the practice of good engineering are precisely the same, whether applied in the designing of the compound or of the ordinary type of steam-engine. The proportioning of the two machines to each other in such manner as to form an effective whole, by procuring approximately equal amounts of work from both, is the only essential peculiarity of compound-engine design which calls for especial care, and the method of securing success in practice may be stated to be, for both forms of engines, as follows:

1st. A good design, by which is meant—

(*a*) Correct proportions, both in general dimensions and in arrangement of parts, and proper forms and sizes of details to withstand safely the forces which may be expected to come upon them.

(*b*) A general plan which embodies the recognized practice of good engineering.

(*c*) Adaptation to the specific work which it is intended to perform, in size and in efficiency. It sometimes happens that good practice dictates the use of a comparatively uneconomical design.

2d. Good construction, by which is meant—

(*a*) The use of good material.

(*b*) Accurate workmanship.

(*c*) Skilful fitting and a proper "assemblage" of parts.

3d. Proper connection with its work, that it may do its work under the conditions assumed in its design.

4th. Skilful management by those in whose hands it is placed.

31. In general, it may be stated that, to secure maximum economical efficiency, steam should be worked at as high a pressure as possible, and the expansion should be fixed as nearly as possible at the point of maximum economy for that pressure. It is even more disadvantageous to cut off too short than to "'follow' too far." With considerable expansion, steam-jacketing and moderate superheating should be adopted, to prevent excessive losses by internal condensation and re-evaporation, and expansion should take place in double cylinders, to avoid excessive weight of parts, irregularity of motion, and great loss by friction.

External surfaces should be carefully covered by non-conductors and non-radiators, to prevent losses by conduction and radiation of heat. It is especially necessary to reduce back-pressure and to obtain the most perfect vacuum possible without overloading the air-pump, if it is desired to obtain the maximum efficiency by expansion, and it then becomes also very necessary to reduce losses by "dead-spaces" and by badly-adjusted valves.

The piston speed should be as great as can be sustained with safety.

The expansion-valve gear should be simple. The point of cut-off should be determined by the governor. The valve should close rapidly, but without shock, and should be balanced, or other device should be adopted to make it easy to move and free from liability to cutting or rapid wear.

The governor should act promptly and powerfully, and should be free from liability to oscillate, and to thus introduce irregularities which are sometimes not less serious than those which the instrument is intended to prevent.

Friction should be reduced as much as possible, and careful provision should be made to economize lubricants as well as fuel.

Guided by these general and fundamental principles of steam-engine practice, a comparison of the work exhibited at Vienna will show that, among stationary engines of the highest class, the American type of engine, with detachable valve-gear, stands at the head of all, and is almost universally regarded as a standard to be copied as closely as possible.

32. EXHIBITED ENGINES WITH DROP CUT-OFF.—The most creditable engine of this class, in the opinion of the writer, was that of Messrs.

Socin & Wick, of Basle, one of the several Corliss engines exhibited. It was rated at 30 horse-power. The valve-gear was that modification of the Corliss, known as the Spencer & Inglis. The engine is an excellent copy, apparently of good material, and of a style of finish and workmanship which indicates, as does much of the Swiss machinery, that the technical school at Zurich is well placed among people who can profit by the teaching which they are receiving from it. The Swiss exhibit a degree of mechanical skill and engineering capacity which places them at least on a level with any other continental people.

33. The steam-engine of Messrs. Sulzer Brothers, of Winterthur, Switzerland, was considered by many of the jury the finest steam-engine in the Exhibition. These makers have gained a reputation in Europe as makers of a very efficient and economical engine, and this feeling and the convictions of the jury were indicated by their award of the highest premium to that firm.

The engine exhibited at Vienna, as illustrative of their best type, was a modified Corliss engine, of excellent construction and well finished, but was in no respect, in the judgment of the writer, superior to a little full-Corliss engine exhibited by Messrs. Socin & Wick. The latter engine, also, possessed all of the simplicity and efficiency of a true Corliss engine, while the Sulzer engine, with its "improvement" in valve-motion, was rendered somewhat more complicated, and probably less perfect in regulation, by the modification.

If the modification of design was made, as is frequently the case, for the purpose of giving the manufacturers a ground upon which to base a claim for superiority, and thus to make a market for an engine having peculiarities of design which they control, the object is readily comprehended, and the advantage of such a change of design, even when the gain of efficiency is in itself of no considerable amount, may be appreciated. In this case the changes introduced were, in the opinion of the writer, rather injurious than beneficial. The engine of Socin & Wick would probably drive as economically, regulate more perfectly, and require fewer repairs.

The Sulzer engine (Figs. 4 and 5) had a steam-cylinder of 17$\frac{3}{4}$ inches diameter and a stroke of piston of 3 feet 5$\frac{3}{8}$ inches. The cylinder was steam-jacketed, and very thoroughly protected by a lagging of cement, felt, and wood, laid one over the other. The frame was similar to that now in general use, and familiar to all engineers, as adopted by Corliss, by Babcock & Wilcox, and by other well-known firms building horizontal engines.

The valve-gear was an ingeniously complex arrangement, embodying some of the devices of Sickles, Corliss, and Greene, and the governor, which is so attached as to determine the point of cut-off, is that of Porter. The whole is a neat combination of devices which have individually been long known in the United States.

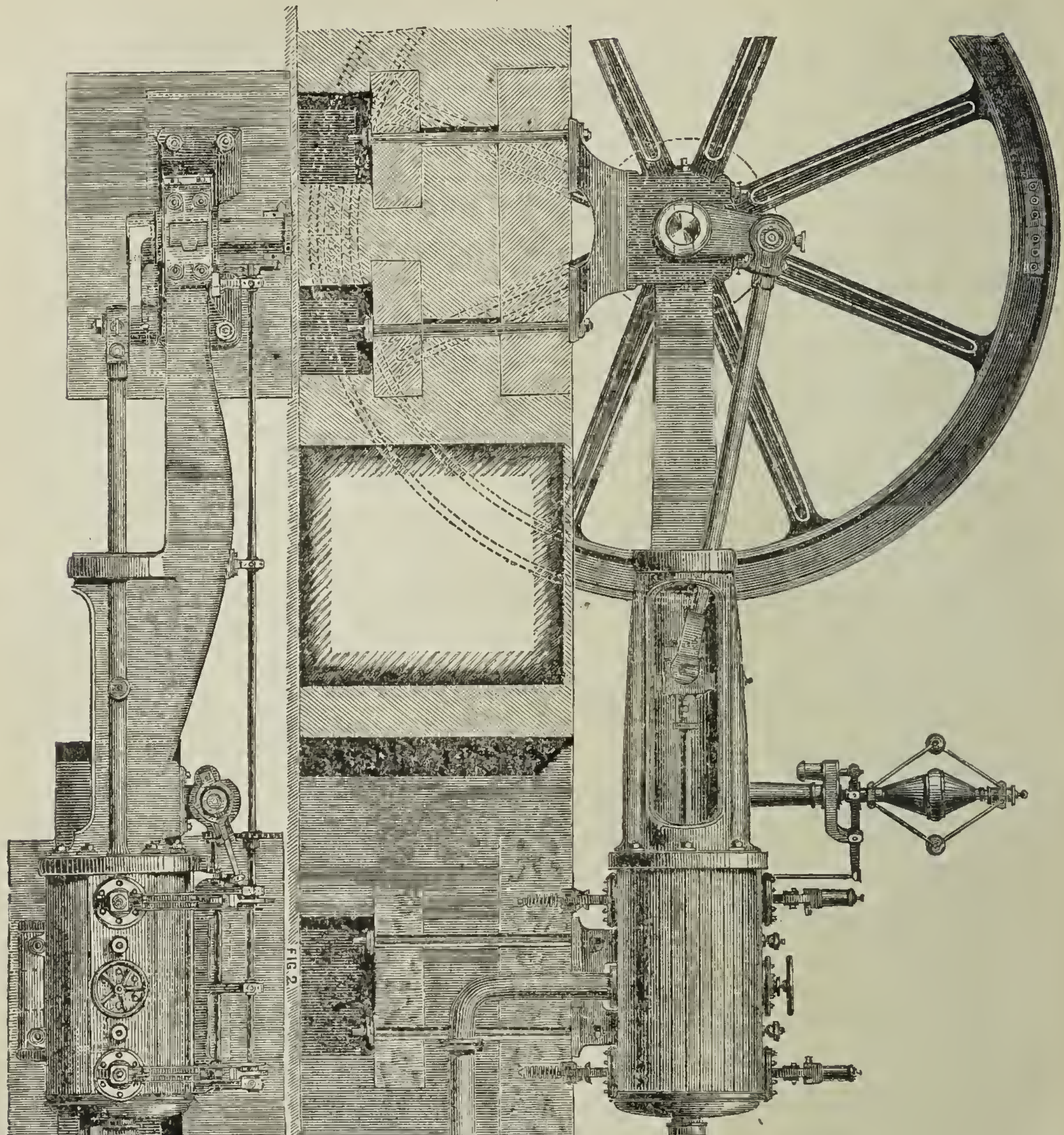

FIG. 4.—Sulzer engine—side elevation.

34. The engine here described is of 70 dynamometric horse-power, when making the somewhat moderate number of 50 revolutions per minute, under a steam-pressure of 75 pounds, and expanding about four times.

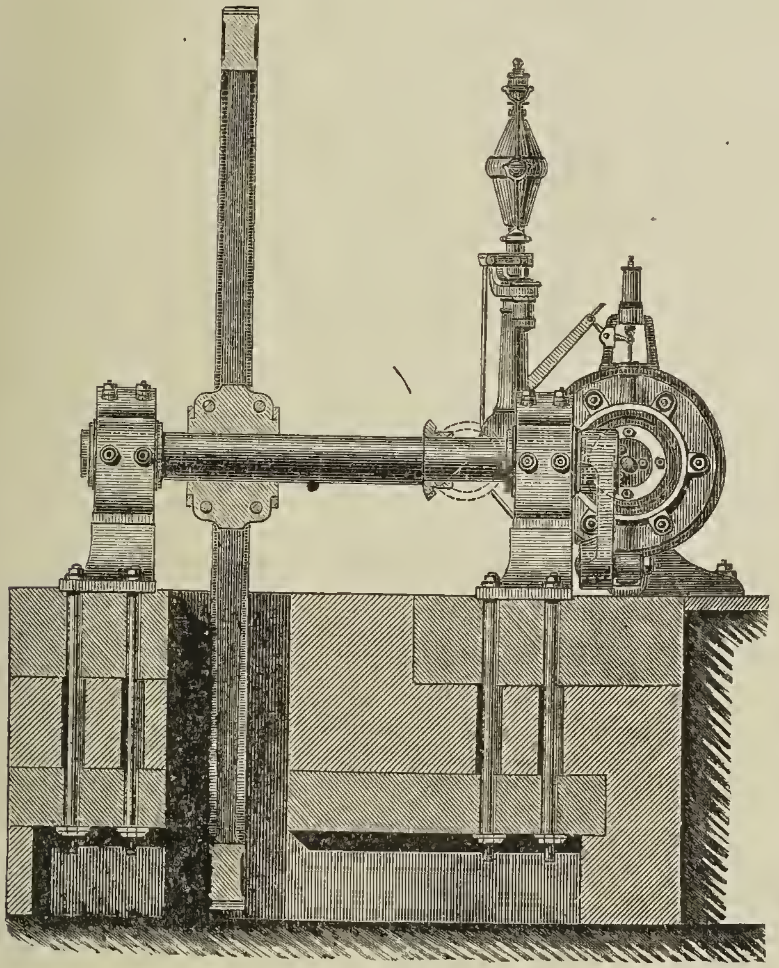

FIG. 5.—Sulzer engine—end elevation.

A similar engine is said to have given an economy which is extremely unusual—$18\frac{3}{4}$ pounds of water per horse-power per hour, and $2\frac{1}{6}$ pounds of coal per horse-power per hour.

The distribution of steam was excellent, as shown by the *fac simile* of an indicator-card here shown, Fig. 6, of which the original was given the writer by the agent of Messrs. Sulzer.

More than a hundred engines of this type and size, varying from 15 to 200 horse-power, were said to have been built by this firm.

On a 400 horse-power engine the makers guaranteed a consumption of less than 20 pounds of water per horse-power per hour; and the makers furnished a minute account of the trial made to determine the question of its fulfilment.

Professor Lindé, who was called to make the determination, reports the following results, giving mean values for a trial of four days:

Steam-pressure, pounds	70.
Pressure in condenser, pound	0.27
Expansions	10.
Indicated horse-power	395.

Dynamometrical power	365.
Consumption of steam per hour per indicated horse-power	19.6
Consumption of steam per hour per dynamometric horse-power*	21.
Consumption of coal per hour per indicated horse-power	3.3
Consumption of coal per hour per dynamometric horse-power	3.5
Water evaporated per pound coal	6.2
Temperature chimney, Fahr	309°

Had the evaporation of water been 10 pounds per pound of coal, the consumption of fuel would have been reduced to less than 2 pounds per indicated horse-power.

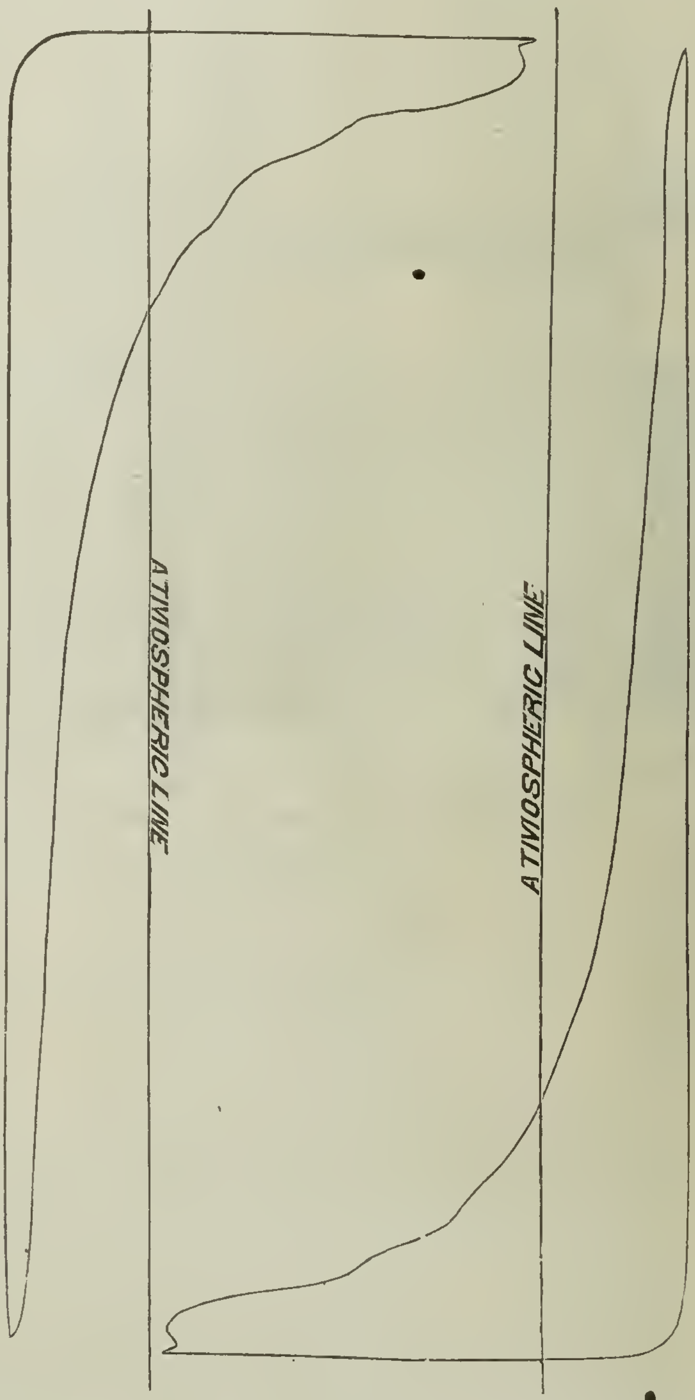

FIG. 6.—Indicator-diagrams from the Sulzer engine.

35. ENGINES WITH OTHER THAN DETACHABLE VALVE-GEAR.—In the construction of the next highest class of engine, that which is

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* It would be interesting to know to what extent this exceptionally low figure is due to working exceptionally dry steam.

adapted to smaller powers or to situations where fuel is not very expensive, or where perfect regularity of movement is not deemed essential, the British builders stand first. Their standard engine, with Meyer expansion-valve, as built by their best firms, represents the best existing practice in this field. In the construction of their portable engines, which are usually of this type, the British manufacturers also excel, and have attained what seems to builders and engineers in the United States a wonderful success in the attempt to secure high economical efficiency.

It is generally thought that with engines of considerable size a consumption of 2½ pounds of coal per horse-power per hour is an excellent performance. This degree of economy has been attained with English portable engines on more than one occasion.

The peculiarities of British practice by which this result is secured seem to be simply a strict adherence to the principles of construction above enunciated and extraordinary care and skill in management.

Of the simplest standard form of steam-engines, there were specimens in the United States section which were unexcelled. The horizontal engine of the Norwalk Company illustrates well a good class of engine, and the vertical engine of the New York Safety-Power Company has no superior in beauty of design or excellence of workmanship. Both of these engines have piston-valves, and only expand steam as far as can be well accomplished by giving lap to the main valve.

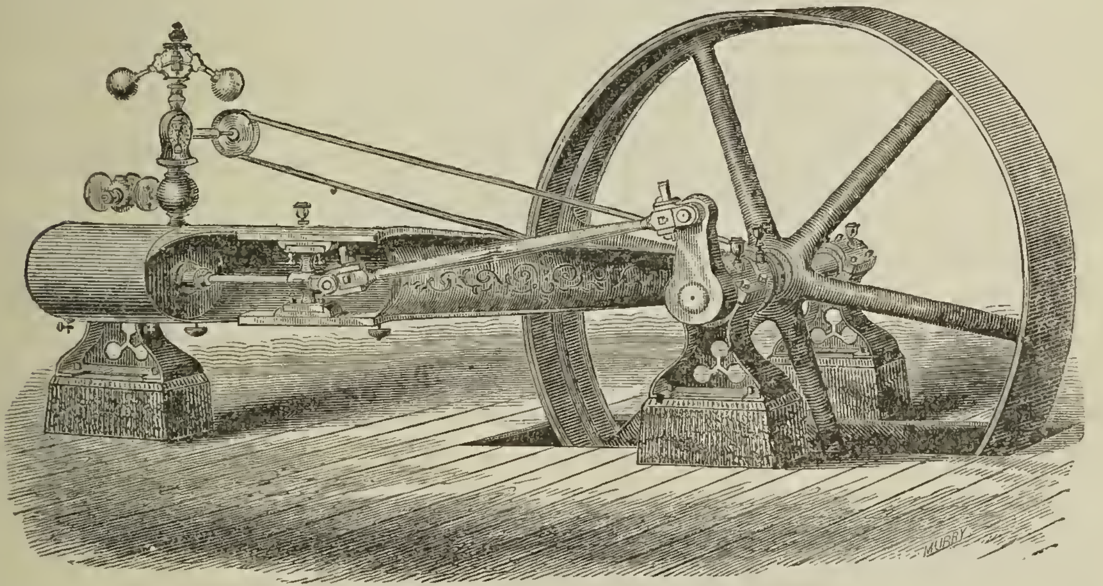


FIG. 7.—Engine of Norwalk Iron-Works.

36. The engine of the Norwalk Iron Company (Figs. 7 and 8) was an excellent example of a very common and serviceable type, of which examples are met with in large numbers of the mills and manufactories of the United States. Figs, 7 and 8 are views, from front and rear, of this engine. The cylinder and bed form a continuous piece, the latter transmitting the longitudinal pull and thrust of the piston directly from cylinder to pillow-block. Two supports, one under the cylinder and the other under

the crank-shaft pillow-block, take the weight of the engine and furnish a means of securing it to its foundation. The cross-head guides are cast with the bed-piece.

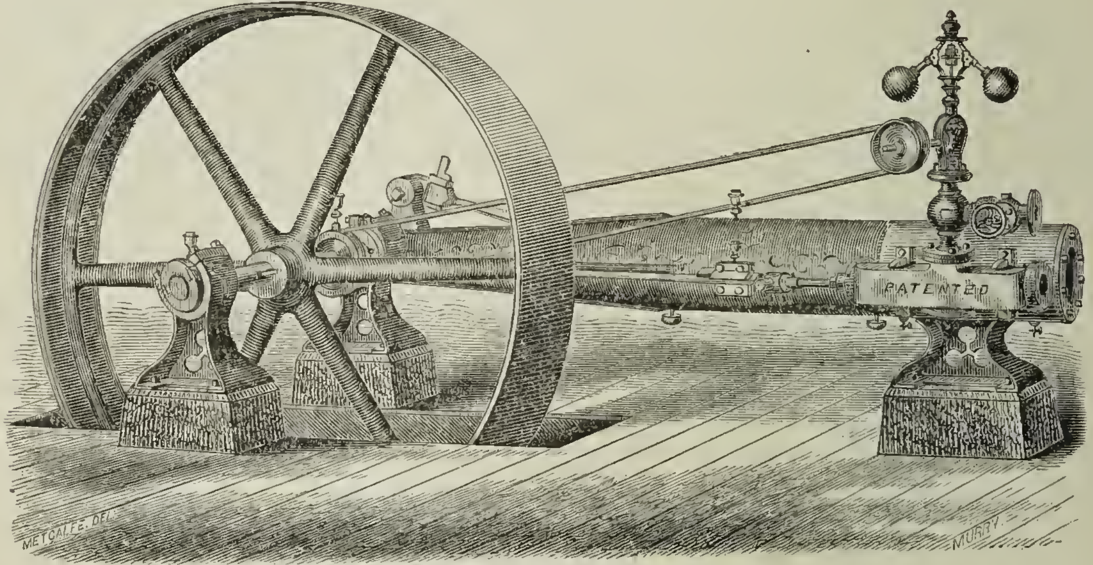


Fig. 8.—Engine of the Norwalk Iron-Works.

The valve used is the Wheeler piston-valve, which consists of two peculiarly-constructed pistons connected by a rod, and is worked by an ordinary eccentric. By a simple arrangement these pistons always have the same pressure inside as out, which prevents any leakage or blowing through, and they are said always to work equally as well and free from friction under one hundred and fifty power pressure as under ten pounds per square inch, and to require no adjustment.

The cut-off valve is not connected with the regulator, but in nearly every respect the engine is most creditable to its builders. It is neat, light, strong, and well finished, and did good work.

37. The accompanying illustrations exhibit the engines shown at the Exhibition by the New York Safety Steam-Power Company, with their details. Figs. 9 and 12 are illustrations of their 10 and 2 horse-power engines; Fig. 10 is a sectional view, and Fig. 11 is an enlarged section of the valve-chest, showing the arrangement of the valves and port. Fig. 13 represents the connecting-rods. These rods are forged in a single piece, having no straps, gibs, or key, to get loose; but are mortised through at each end for the reception of the brass boxes, which are curved on their backs, and fit the cheek-pieces, between which they can turn, to adjust themselves to the pins, in the plane of the axis of the rod. The adjustment for wear is made by the wedge-blocks and the set-screws, as shown, and they are so constructed that the parts cannot get loose and cause a break-down, as not unfrequently happens with engines of the ordinary construction. Fig. 14 exhibits the cross-heads. They have adjustable gibs on each side, turned to fit the slides, which latter are cast solidly in the frame, and bored out exactly in line with the cylinder. This permits the cross-head to freely turn on its

axis, and, in connection with the adjustable boxes in the connecting-rod, it allows a perfect self-adjustment to the line of the crank-pin. By adopting this arrangement, the out-board bearing may be moved an inch or more out of position in any direction, without detriment to the engine, every bearing accommodating itself perfectly to whatever position the shaft may assume. Fig. 15, page 30, illustrates the pillow-blocks They have a spherical shell, turned and accurately fitted into the spherically-bored pillow-block, thus allowing a slight angular motion in any direction, and providing neatly and effectively against the heating of journals by getting out of line.

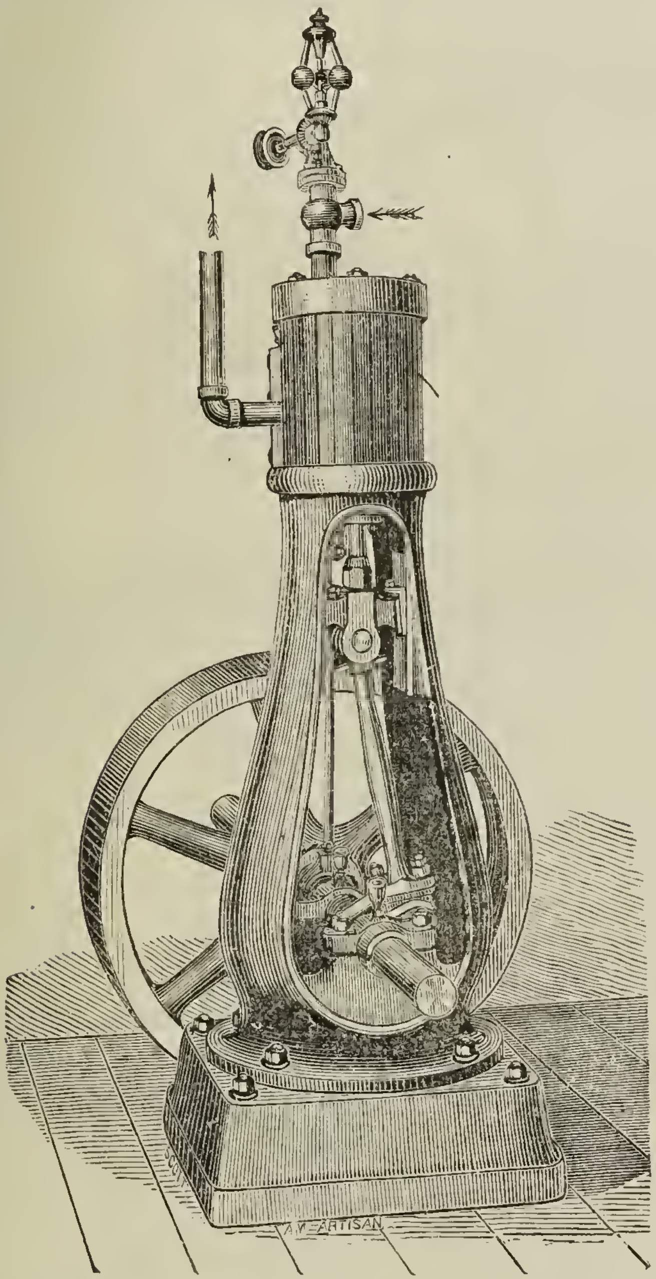


FIG. 9.—New York Safety Steam-Power Company's engine.

These engines were unexcelled in compactness, in neatness of design, elegance of proportions, or excellence of material and workmanship, by any engines of similar class in the Exhibition. They may justly be regarded as exceedingly creditable representations of the best American practice in the design and construction of engines of small power.

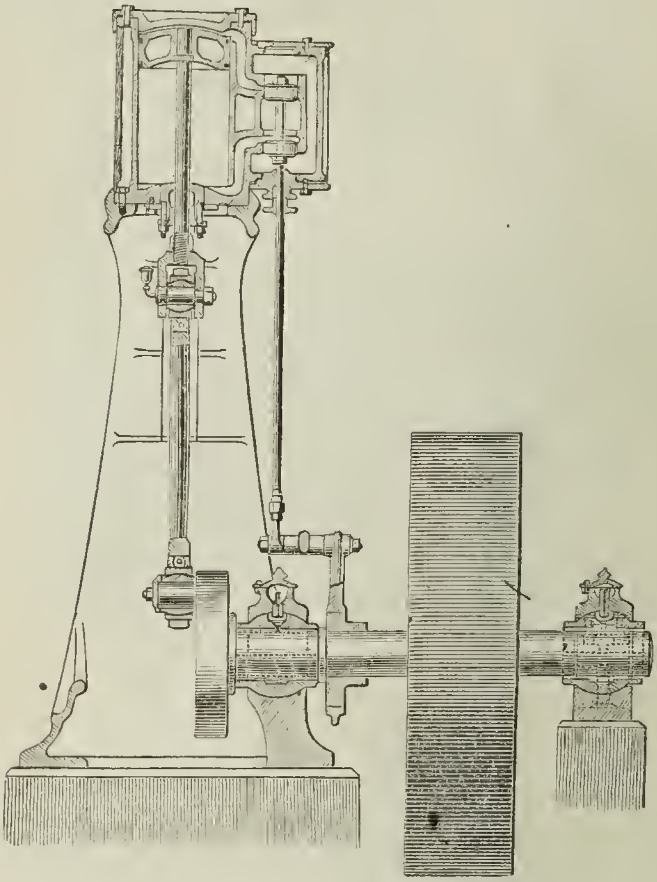


FIG. 10.—Vertical section.

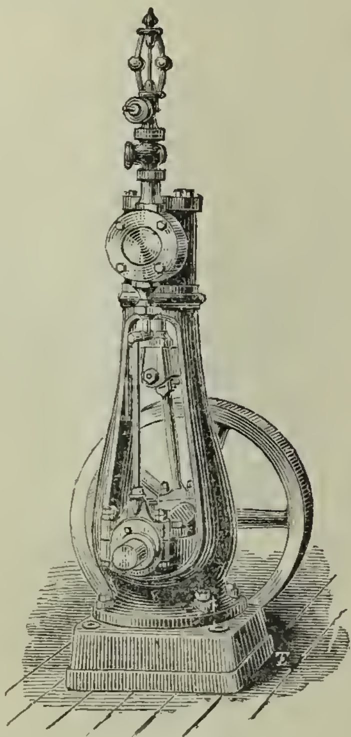


FIG. 12.

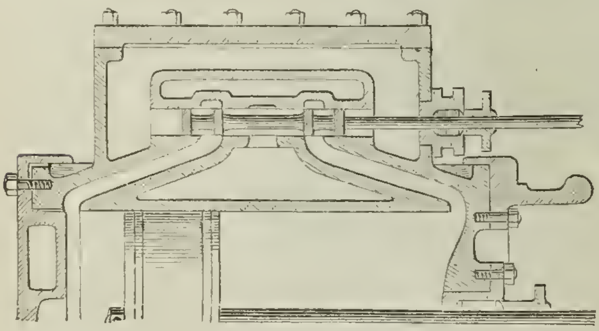
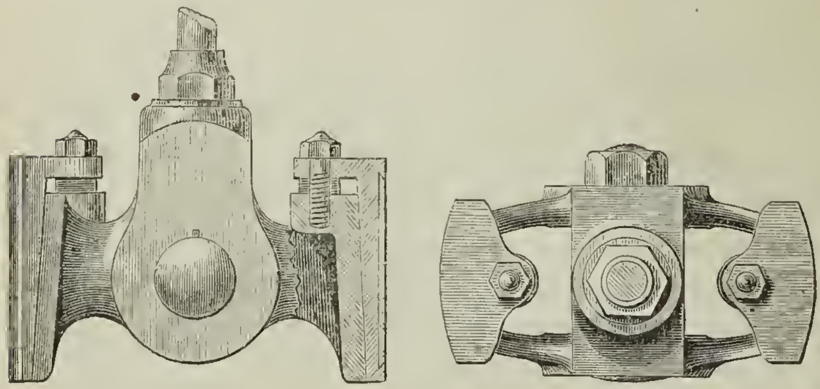


FIG. 11.—Section of valve and steam cylinder.



Side view. FIG. 14.—Cross-head. End view.

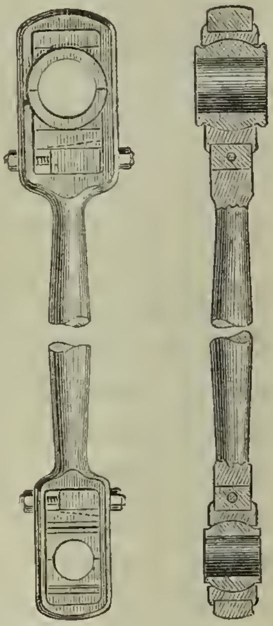


FIG. 13.—Connecting-rods.

The builders of these engines state that they fit up considerable numbers of their engines in small steam-yachts.

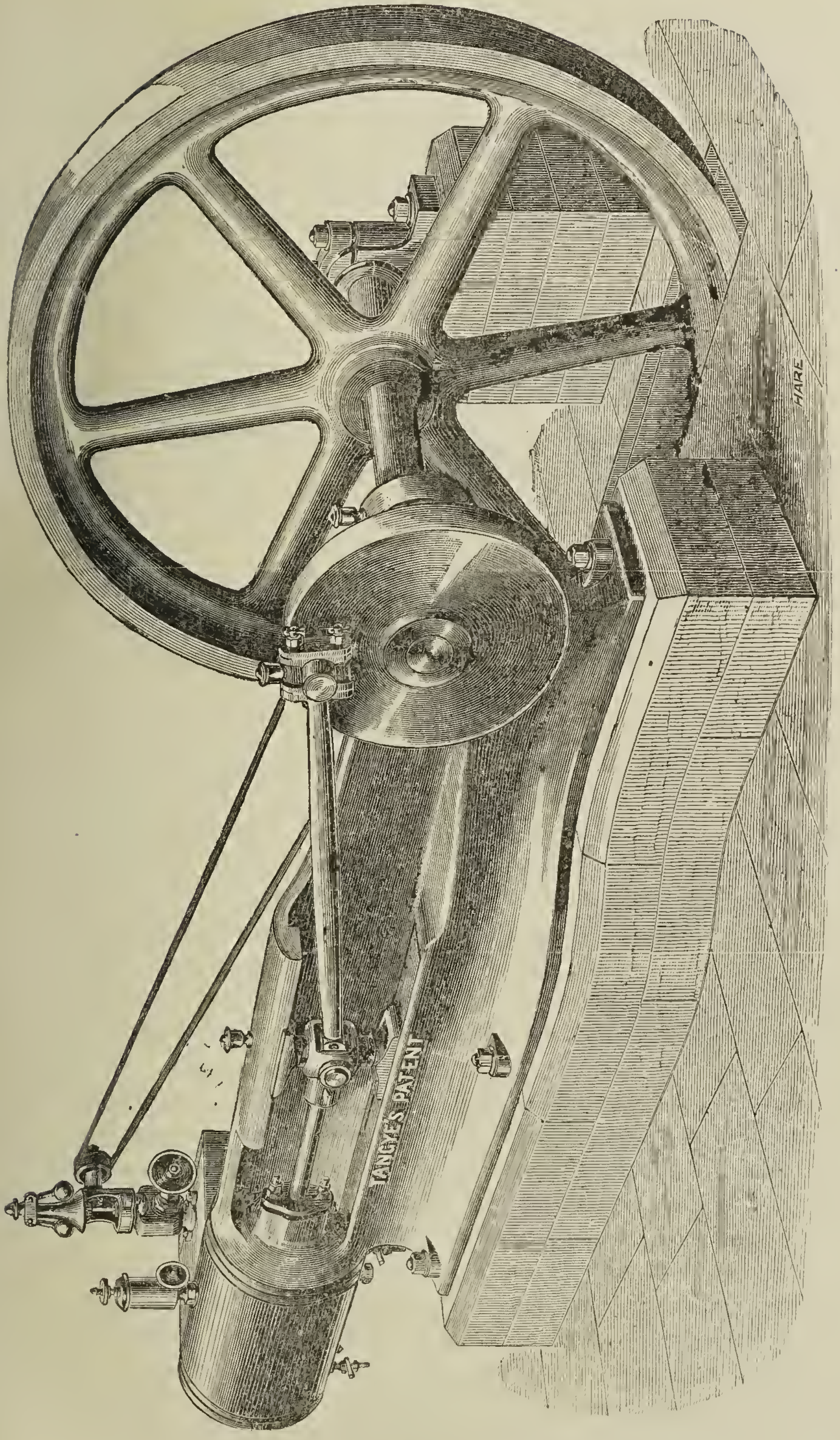


Fig. 16.—Tangye's stationary steam-engine.

38. The engine of TANGYE BROTHERS, of Birmingham, England, shown in the accompanying illustration, Fig. 16, is an example of an excellent British stationary steam-engine. It is simple, strong, and efficient. The

frame, front cylinder-head, cross-head guides, and crank-shaft plumber-block are cast in one piece, as has so generally been done in the United States for a long time by some of our manufacturers. The cylinder is secured against the end of the bed-plates as was first done by Corliss, ten or fifteen years ago. The crank-pin is set in a counterbalanced disk. The valve-gear is simple and the governor effective and novel, and provided with a safety-device to prevent injury by the breaking of the governor-belt.

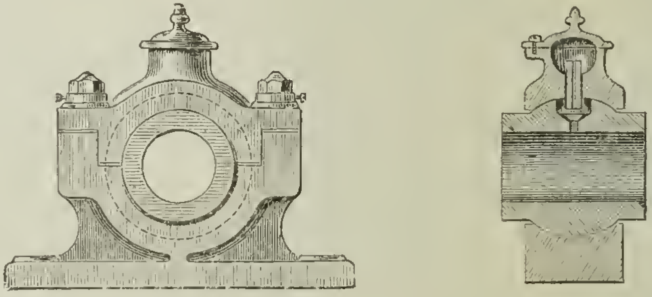


FIG. 15.—Pillow-blocks.

39. COMPOUND ENGINES.—The compound stationary engines exhibited do not require extended mention. They are few in number, and, as already remarked, are not usually remarkable for good design or for good workmanship.

Messrs. W. & J. GALLOWAY, of Great Britain, exhibited a plain substantial, well-built machine of this class, of which a view is given in the accompanying engraving, Fig. 17. It was intended for a mill-engine, and seemed quite well adapted to such use. Its steam-cylinders were 14 and 24 inches in diameter, respectively, with 30 inches stroke of piston. The cranks were set at angles of 180°, the pistons moving in opposite directions. The crank-pins were set in disk-cranks. The valve-gear was of the usual type of slide, with cut-off valve on the back, adjusted by the regulator. The governor was of peculiar design, embodying the principle of the Porter governor, and determined the point of cut-off by moving a link. The cylinder was not steam-jacketed.

A condenser and air-pump were attached, the latter having a diameter of 8 inches, and, being driven by the extension of the piston-rod of one engine, had the same stroke, 30 inches. The engine was worked under a pressure of 60 pounds per square inch, and formed a vacuum of 28 inches of mercury. It was rated at 100 horse-power.

40. The best example of a finely-finished stationary compound engine was that exhibited by the MM. SCHNEIDER, of Creuzot, France. It was of the now common *marine* type in its general design, of 100 or 120 horse-power. It was well proportioned, and had been given a most remarkably fine finish, which exhibited well the excellence of its material. It was too extensively polished and too expensively finished to represent standard work.

In the accompanying plates, Fig. 18 represents this engine in vertical section; Fig. 19 is a plan, with horizontal section of the steam-cylinders, showing their relative magnitude and general disposition;

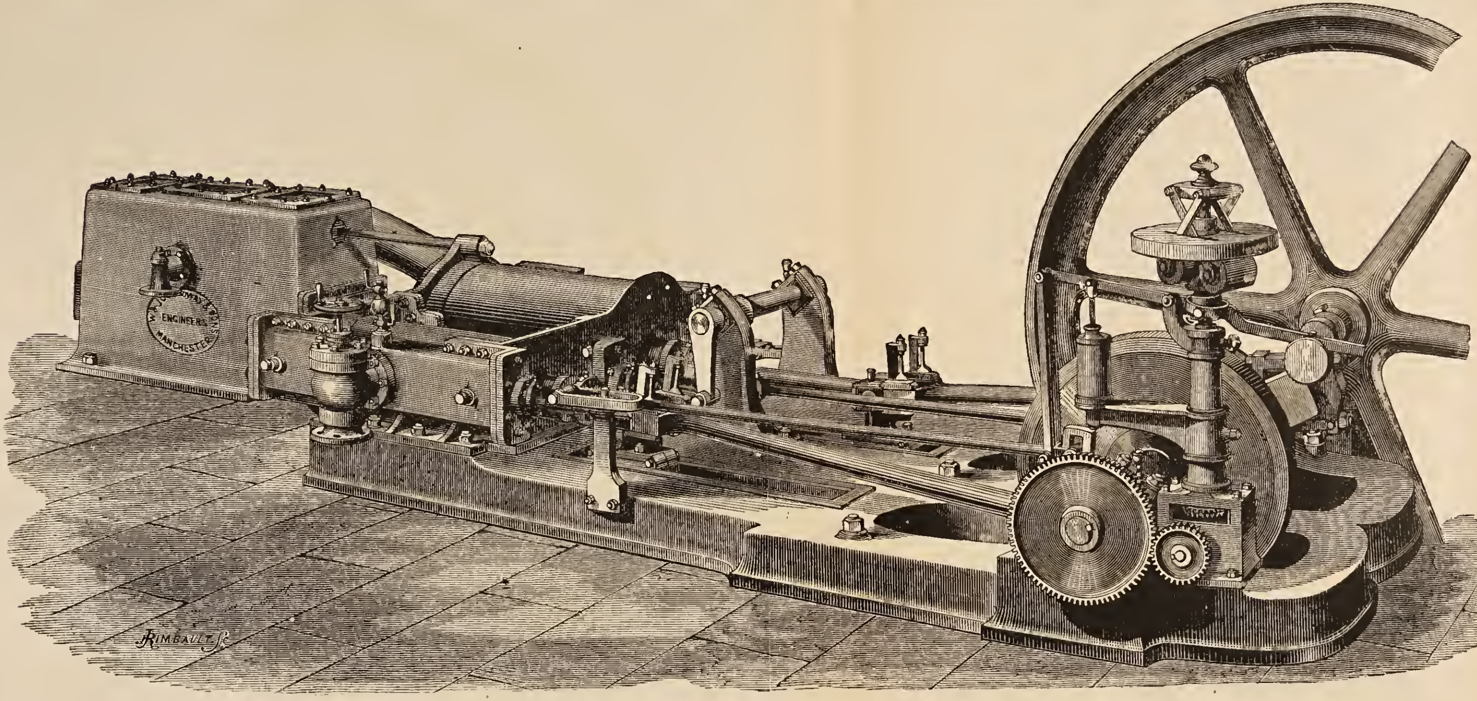


FIG. 17.—The Galloway compound steam-engine.

Fig. 20 is a vertical longitudinal section, exhibiting the arrangement of ports and valve-gear, and Fig. 21 is a horizontal section along the shaft-line.

The steam-cylinders were 9½ and 15¾ inches diameter, and the stroke of piston was 23⅝ inches. The cranks were arranged at right angles, as practiced by Napier. The details of the design were, in some respects, faulty. The high-pressure cylinder was surrounded by a jacket which received the exhaust-steam—a very ingenious device for producing waste of heat. This exhaust-jacket was also made large to perform the part of the intermediate receiver required on this form of engine, and was probably larger than was needed. It had several times the capacity of the small cylinder; it would be equally, if not more, efficient if made of equal size with that cylinder, or very little larger.

The frames were hollow, strong, neat, and well placed, and the interior was used as a condenser, a practice which has now become very general. The single air-pump was placed back of the frame, and was worked by a beam, or lever, linked to the cross-head in the usual way. Its dimensions were 9 inches diameter and 11⅞ inches stroke. It was single-acting.

The cut-off valve on the smaller cylinder was worked by an independent eccentric, which was so arranged as to be adjustable for different ranges of expansion. No expansion-valve was provided for the low-pressure cylinder. The grade of expansion could be varied by means of the valve on the high-pressure cylinder to a minimum of about one-ninth or one-tenth. As customarily set, it would suppress admission at about one-fourth.

Regulation was effected by a governor acting upon a valve in the steam-pipe—a method of less efficiency than that generally practiced in the United States, of adjusting the point of cut-off by the governor. The governor was of the approximately parabolic form with cross arms; the governor-valve was Schneider's patent equilibrium valve.

41. The most striking design of compound engine was that designed by L. Ehrhardt, and exhibited by the Dingler'sche Maschinenfabrik, Zweibrücken. The two cylinders were side by side, and incased in one large cylindrical jacket. The cranks were placed at angles of 180°, the pistons moving in opposite directions. The remarkable peculiarity of the design, and that which attracted most attention, was the use of continuously-revolving cylindrical valves, very similar to those introduced in the United States many years ago by Thomas Goodrum. The governor is attached to determine the point of cut-off in a manner also similar in principle to that of the American inventor. This engine was the quietest and most smoothly-running engine at Vienna, and is an excellent example of a combination of devices, nearly all of which are familiar to many American mechanics. Its general plan was the invention of Hornblower, and is a hundred years old, and the cranks were similarly arranged by Randolph & Elder a quarter of a century ago. The valves are those of Goodrum. The piston is without rings, and has a broad

bearing, like pistons which have been long used on the Mississippi River. The governor is that of Porter, an invention which seems, like the Pickering governor, to have become well known and largely introduced in all European countries. The steam-jacket is no novelty.

The members of the International Jury, Group XIII, were furnished copies of a pamphlet written by the designer, in which he reviews this engine and states his reasons for adopting the general plan and for its peculiarities of detail. He presents a *résumé* of the advantages and disadvantages attending the use of steam for high pressure with great expansion, and gives, as the causes of the discrepancy observed between the results shown to be theoretically attainable and those actually reached in practice, the facts that—

(*a*) The size and weight of the machine in all its details must be so much increased as to introduce excessive friction with a comparatively low mean steam-pressure. The ratio of useful to lost work becomes thus reduced seriously.

(*b*) The condensation of steam at the beginning, and its re-evaporation at the end, of the stroke become causes of loss which losses become rapidly more serious as the difference of temperatures and pressures at the two extremes becomes greater.

(*c*) The difficulty of keeping the valves and piston steam-tight becomes, with high pressure, very serious.

(*d*) To reduce this loss, high piston-speed is demanded, as the loss is constant for equal times, whatever the speed, and thus an increase of speed reduces the ratio of loss to utilized heat and work.

He therefore concludes, with Völkers, that—

(*e*) The boiler of the high-pressure engine must be made stronger and in all ways better than that of the engine working under lower pressure

(*f*) The engine itself must be made stronger, of better material, and of better workmanship.

The designer concludes that the point of cut-off on the single cylinder with low piston-speed, for maximum efficiency, when carrying 90 pounds of steam, is at about one-eighth, a somewhat greater expansion than the writer has found best, unless, possibly, with very well built engines, working dry steam, in well-jacketed cylinders, and at a very high speed of piston. He concludes that high piston-speed is an essential element of efficiency, a conclusion previously arrived at and long practiced by builders in the United States.*

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* The following principles were enunciated by the writer previous to 1860:

"REQUISITES OF ECONOMICAL MARINE ENGINES.—A speed of piston of $300\sqrt[3]{\text{stroke}}$, or higher.

"A mean pressure as high and as near the boiler-pressure as possible for the given expansion.

"A steady movement of the paddle-wheel or screw.

"A maximum diameter of paddle-wheel, or the minimum area of screw-disk compatible with minimum total resistance of the propelling-instrument. Proportion of boiler heating-surface to grate such as to reduce temperature of escaping gases to minimum needed for draught. Ample space in boiler combustion-chamber to permit thorough intermixture and perfect combustion. Heated surfaces to be thoroughly covered with non-conductors."

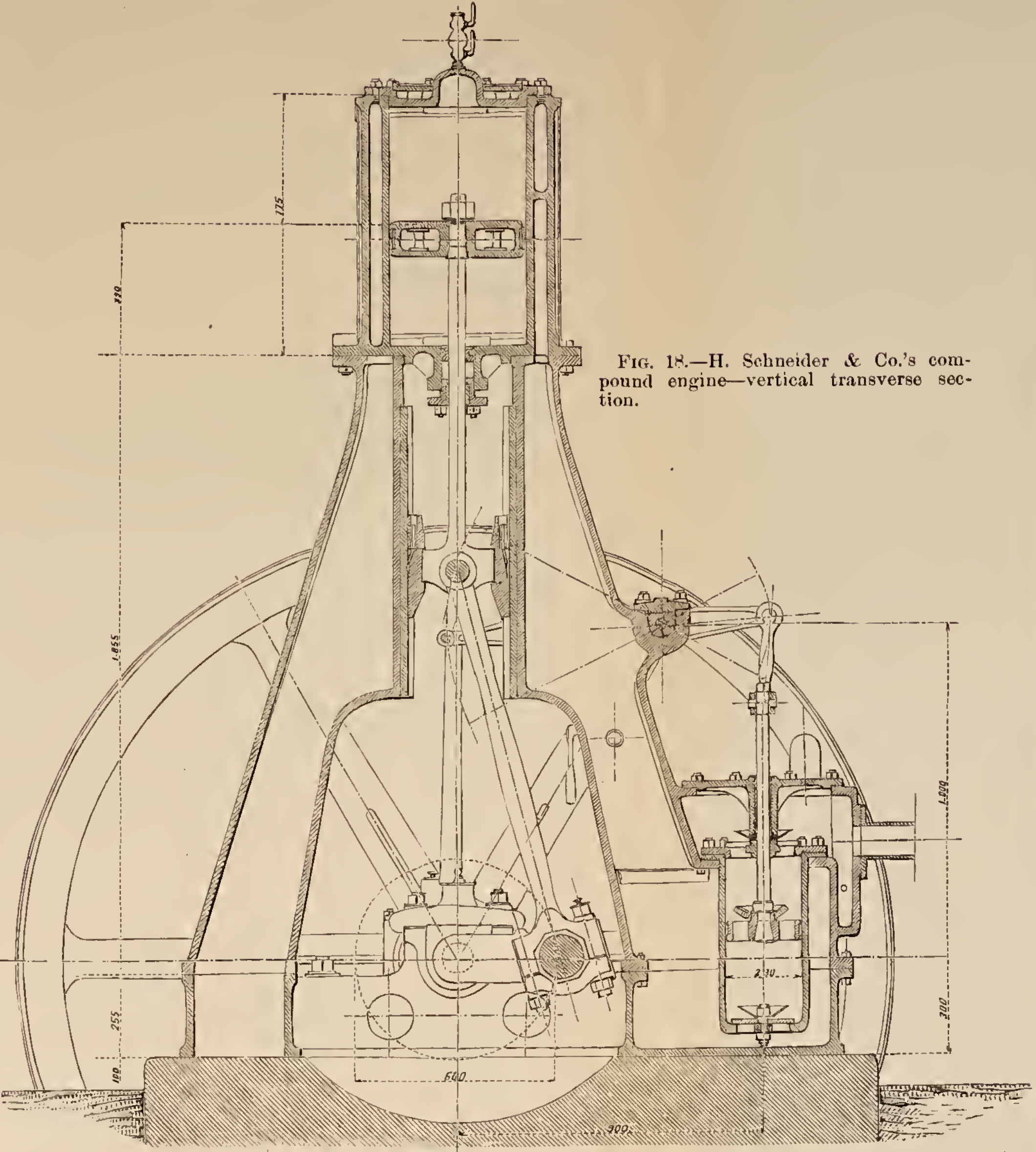


Fig. 18.—H. Schneider & Co.'s compound engine—vertical transverse section.

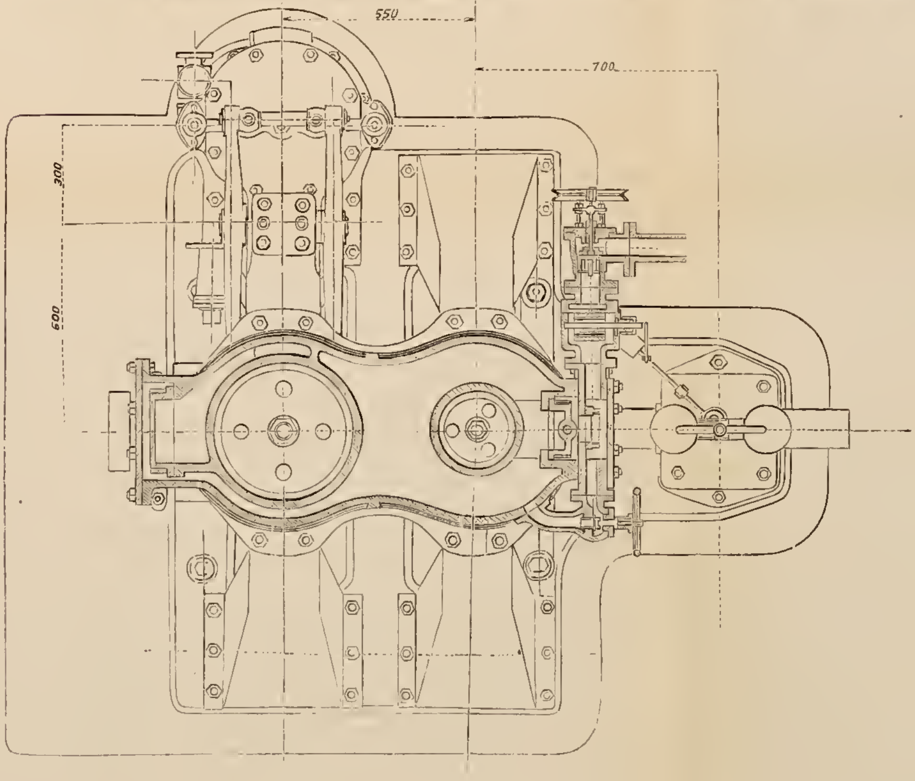
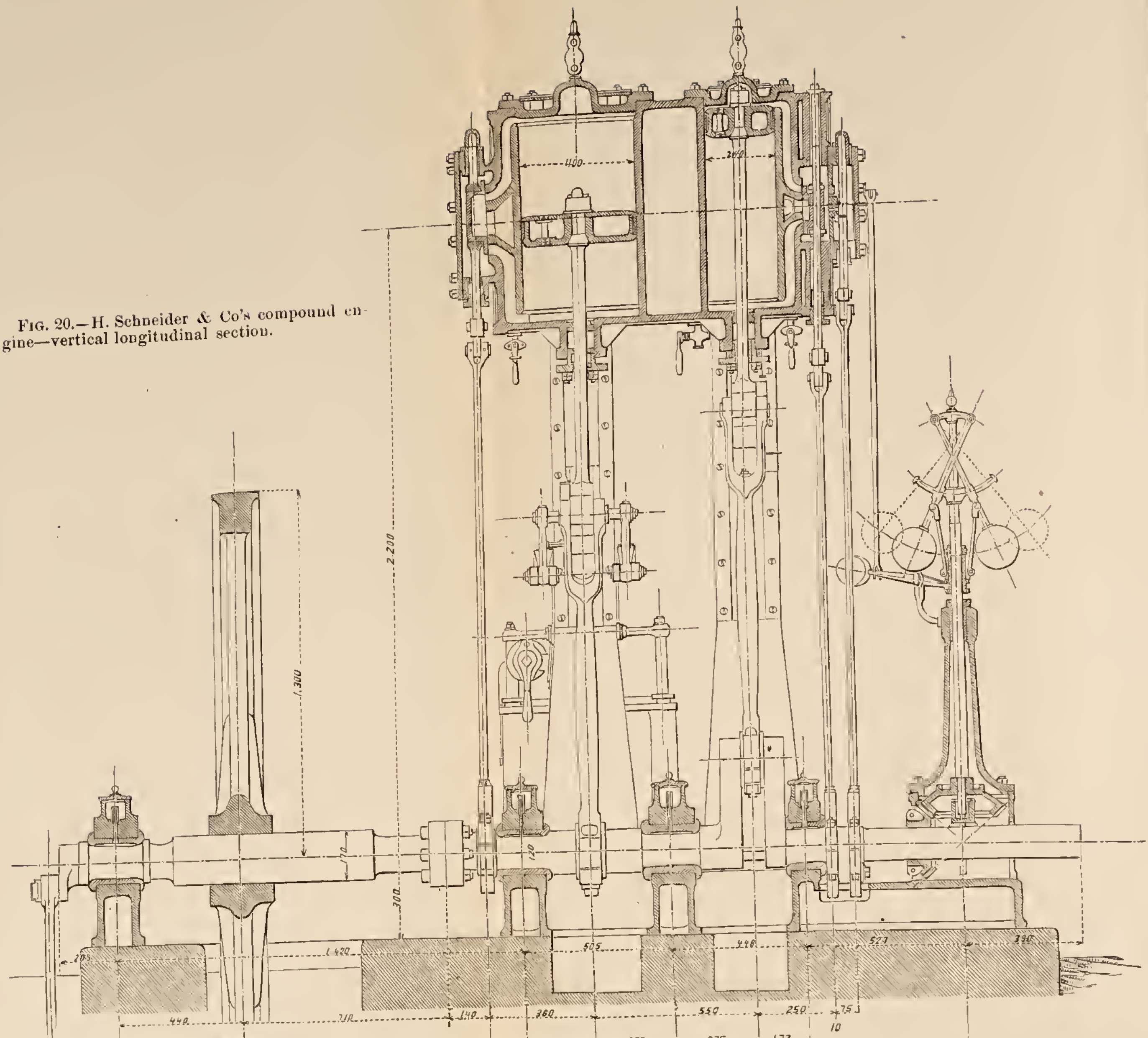


Fig. 19.—Plan, with horizontal section through cylinders.

Fig. 20.—H. Schneider & Co's compound engine—vertical longitudinal section.



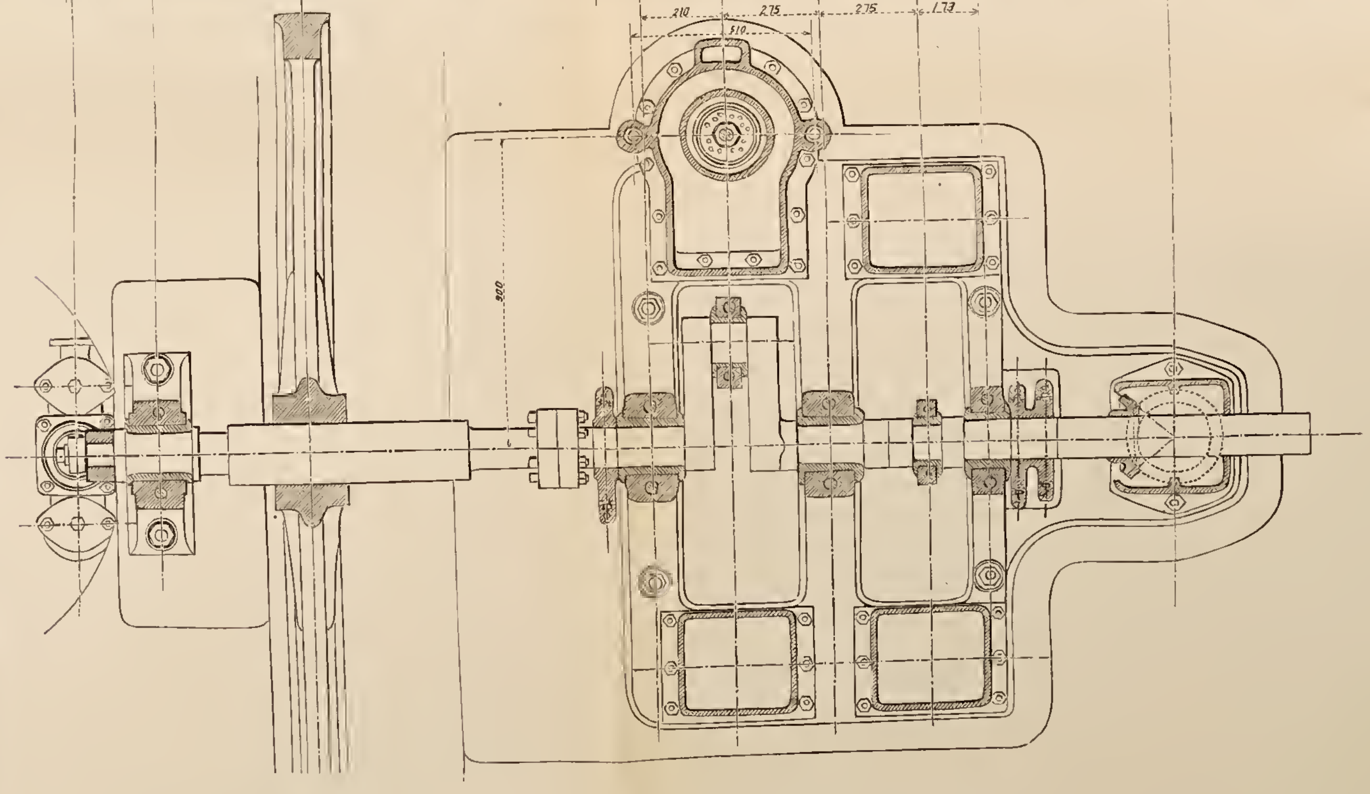


Fig. 21—Plan and horizontal section through shaft-line.

Ehrhardt, therefore, considering none of the existing designs satisfactory, attempts a new and entirely original plan. He has probably invented all of the devices claimed, but it curiously happens that in all he has been anticipated by independent invention in this country.

He works with a steam-pressure of about 150 pounds per square inch, expanding about ten times. The degree of expansion is, however, variable. His cylinders at Vienna were 4$\frac{15}{16}$ and 9$\frac{7}{8}$ inches diameter, respectively, the stroke of piston 19$\frac{5}{8}$ inches in each.

The speed of piston was very nearly 390 feet per minute.

The two cylinders of the engine at Vienna were covered by one cylindrical casing which gave the whole the appearance of a single large cylinder. The whole was well lagged and carefully protected against losses of heat by radiation and conduction. The piston has no rings but is carefully fitted, and must be rebuilt when it or the cylinder becomes worn and leaky.

42. Beside the description of this engine, and this statement of the claims of the designer, may properly be placed the following statement by Mr. Charles T. Porter of the peculiar features of the Porter-Allen engines built by him, the representative high-speed single-cylinder engine in the United States:

"Their distinctive features are as follows:

"(*a*) *Rapid piston-speed.*—From 600 feet per minute in the smallest sizes to 800 feet in the largest.

"(*b*) *Short strokes.*—Varying, in the different sizes, from twice to about once and a half the diameter of the cylinder.

"(*c*) *Rapid rotation.*—The revolutions per minute ranging from 300 in the smallest to 100 in the largest engines.

"(*d*) *Heavy reciprocating parts.*—These are calculated to absorb about one-half of the force of the steam at the commencement, and give it out to the crank at the termination of each stroke, compensating for the inequalities of pressure occasioned by working expansively, giving smoothness of running, and enabling the builder to employ—

"(*e*) *Small and light fly-wheels.*—These are only from one-half to one-third the size usually required on engines giving the same power, but are sufficient to maintain a very uniform motion.

"(*f*) *A variable cut-off in which the valves have positive movements.*

"(*g*) *Four-opening equilibrium admission-valves, with adjustable pressure-plates.*—This is an admirable feature, especially in its adaptation to high speeds, admitting and cutting off the steam in a very perfect manner, working without friction under the greatest pressures, easily kept tight, and relieving the cylinder from confined water.

"A maximum diameter of paddle-wheel, or the minimum area of screw-disk compatible with minimum total resistance of the propelling instrument.

"Proportion of boiler-heating-surface to grate, such as to reduce temperature of escaping gases to the minimum needed for draught.

"Ample space in boiler-combustion-chamber to permit thorough intermixture and perfect combustion.

"Heated surfaces to be thoroughly covered with non-conductors."

"The exhaust is by four-opening valves working under the pressure in the cylinder.

"This system of valves and valve-gear is the invention of Mr. John F. Allen.

"(*h*) *The Porter governor.*—Giving great regularity of running under extreme changes of resistance."

Its short stroke enables entire solidity to be attained in a bed of rigid form, making it a very completely self-contained engine, adapted to the heaviest work, and requiring only a small foundation. Solidity and simplicity mark all parts of the design.

The journals of the shaft, and all cylindrical wearing-surfaces, are finished by grinding in a manner that leaves them perfectly round. The crank-pin and cross-head pin are hardened before being ground.

The joints of the valve-gear consist of pins turning in solid ferrules in the rod ends, both hardened and ground. These are found to be extremely durable. Seven years of constant use show, as claimed, no wear to occasion lost time in the valve-movements; but in these engines, besides the fact that the valve-gear needs no looking after, the valve-action is found to be the same after years of running.

The lubrication is self-acting and reliable throughout. Should it be run continuously, as it may be for an indefinite time, the lubricators may all be filled and adjusted with the same facility as if it were standing.

The advantages attained by such a combination are, according to Mr. Porter—

First. *Great power in small compass.*—This is obtained by the high speed and short stroke, and by carrying the steam further before cutting off than is common in engines working expansively. Cutting off earlier than at one-quarter of the stroke, in the opinion of the builder, is always attended with loss.

The powers given in the builder's table are said to be fully realized in engines running. They are calculated for 80 pounds pressure, cut off at one-quarter of the stroke.

Second. *Superior economy.*—High speed and short strokes are considered by Mr. Porter essential elements of economy. It is now well understood that all the surfaces with which the steam comes in contact condense it; it is also coming to be known that the extreme claims to economy often put forward are in a large degree fictitious, and that the engines will not stand real tests. The condensation on the interior surfaces of the cylinder, heads, and piston, chilled by re-evaporation during the expansion, and especially during the exhaust, is the chief cause of a loss, which makers try to hide.

Obviously, the way to diminish it is to reduce the extent of surface to which the steam is exposed. In these engines, on account of the rapid speed and short stroke and later cut-off, the surfaces with which the steam comes in contact, while doing a given amount of work, do not

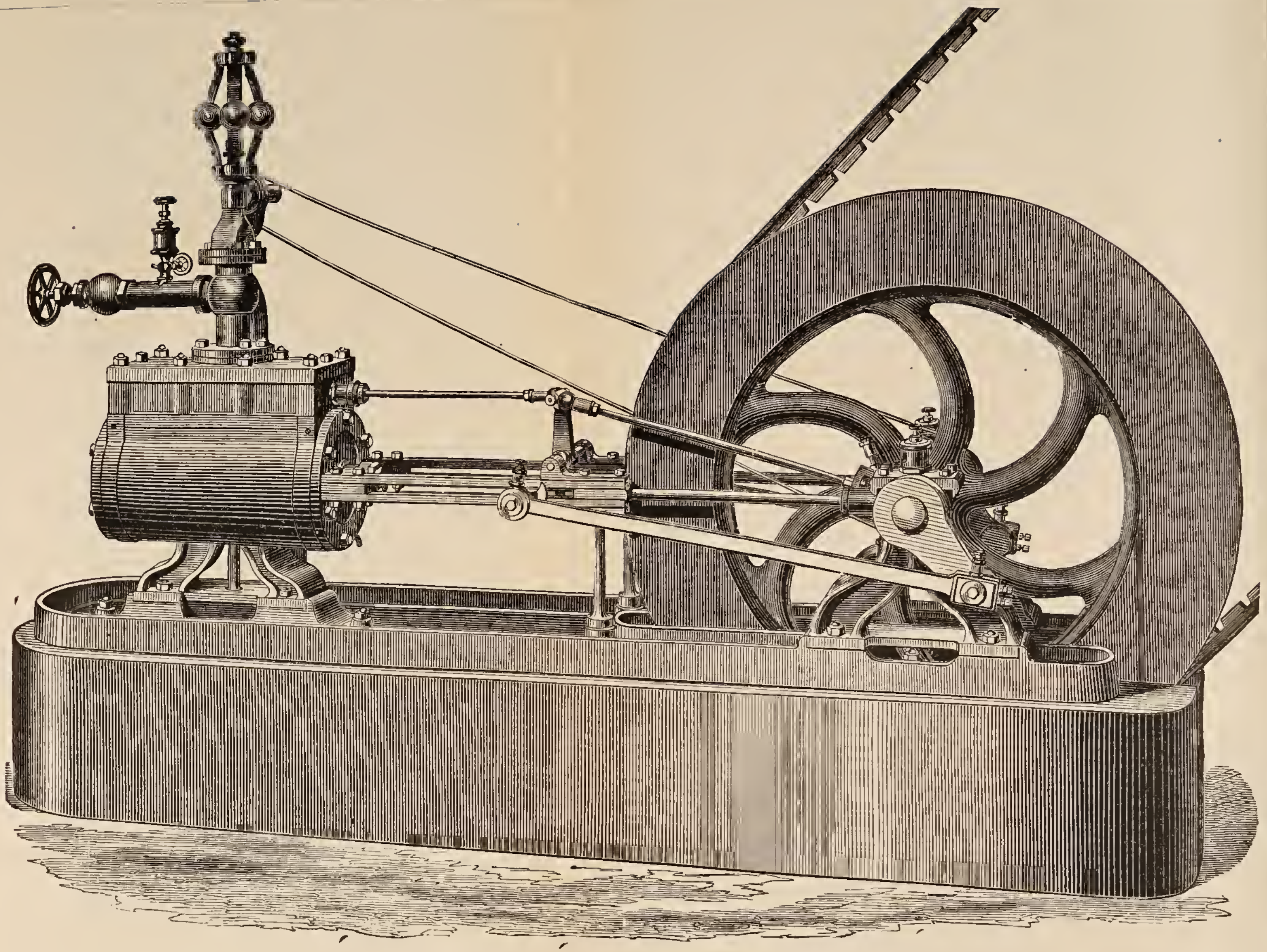


FIG. 22.—Pickering & Davis steam-engine and regulator.

average in extent more than one-third that found in ordinary expansion engines. This is the cause of an economy that slow-speed engines cannot attain.

Third. *Power transmitted by parallel belts.*—This engine possesses the advantage of driving by a parallel belt. Converging belts, transmitting power from great pulleys on the engine-shaft to small ones on the line, involve serious difficulties. In this engine the speed is attained at the engine-shaft, the belts are practically parallel, and may be as short as convenience requires; and, the upper belt being made the loose one, they may always be in contact with more than one-half the circumference of the smaller pulley.

Fourth. *Economy in first cost.*—Besides the saving in transportation, foundations, connections, room, and fuel, such an engine can be afforded at a low price per horse-power.

Where great steadiness of motion is desired, the expense of coupled engines is often incurred. These engines never require to be coupled; a single engine is found to give greater uniformity of motion than is obtained with coupled engines at ordinary speeds.

The speeds prescribed by the maker, in reality, have been considerably exceeded in successful practice. They are speeds settled by experience, and for which the engines are in all respects designed; the ports and valve-movements, the weight of the reciprocating parts, and the size and weight of the fly-wheels are calculated expressly for them.

For special purposes, such as direct connection with lines of shafting, or with trains of rolls, dispensing with gearing, engines of even shorter stroke are made, adapted for any speed up to 500 revolutions per minute.

One of these engines was exhibited at the Paris Exhibition of 1867. It is much to be regretted that another could not have competed with this, the only European rival in 1873. Its economy was stated, in 1870, by a committee of the American Institute of New York, President F. A. P. Barnard, of Columbia College, chairman, to have exceeded that exhibited by two others of the best "drop-cut-off" engines exhibited previously at the same place.

It would be very interesting and probably instructive to embody the principles of the Porter-Allen engine in a compound engine. There would then be combined to an extent previously untried the requisites of high, economic efficiency.

43. PECULIAR DESIGNS.—Among the peculiar designs of stationary engine which attracted much attention was the PICKERING ENGINE and governor, illustrated in the accompanying engraving, (Fig. 22.) In designing this engine, one of the chief points kept in view seems to have been to dispense with the usual bed-plate, and to resist the strains due to the action of the steam on the piston by a direct connection between the cylinder and the crank-shaft bearings. The engine has no bed-plate; the casting to which the cylinder and the crank-shaft bearings

are bolted is merely a light cast-iron tray to catch the oil dripping from bearings and guide-bars. The strains due to the thrust and pull of the connecting-rods are taken by the guide-bars, which in this engine are also used as stays connecting the cylinder-head to the crank-shaft plumber-blocks. The fly-wheel runs between the two plumber-blocks, while the crank-shaft, which is very short, has a crank at each end and a pair of connecting-rods coupling the cranks to the cross-heads. By this arrangement the usual cast-iron bed or frame, with a sectional area of ten or twenty times that of the piston-rod, is dispensed with, being replaced with light wrought-iron stays of a sectional area of but one and a quarter times that of the piston-rod. The crank-shaft is also not only shorter than with other styles of engine, but lighter, as the power, instead of being wholly transmitted from one end, is received by the fly-wheel equally from each end. The position of the fly-wheel is such that its weight tends to prevent the vibration usually noticeable in small, high-speed, reciprocating engines. This engine has a cylinder 6 inches in diameter, with 12 inches stroke of piston, the piston-rod being made of cold-rolled iron, not turned in a lathe; the valve-spindle is made of cold-finished, unturned steel. A close examination of this piston-rod and valve-spindle showed that they had as good a surface and were as perfectly cylindrical as they would have been if carefully finished in a lathe.

The engine was fitted with an ordinary slide-valve; motion was transmitted from the eccentric to the valve-spindle through a rocking-arm, as shown. Speed was controlled by one of Pickering's spring governors. It consists of three balls mounted on springs of thin plate-steel, as shown in the engraving; the ends of the springs are secured to flanges, the lower of which, resting on steel washers, and having a collar to prevent its rising, is capable of only a rotary motion, while the upper one, being at liberty to move lengthwise as well as to rotate, receives its rotary motion from the lower one, through the springs, and communicates any lateral motion due to the varying centrifugal force immediately to the balanced valve, to which the governor is firmly secured by the brackets, a part of which forms a long bearing for the horizontal spindle, which communicates motion from the power to the governor through the miter-gearing. The object of this latter invention is to obtain the requisite centripetal force without making the springs too heavy. It consists in the peculiar construction of the spring and in the shape of the curve given it by the manner in which the ends and middle portion are secured, keeping those parts at all times parallel with the center of motion. By this arrangement steel can be used so thin that all liability to break, or tendency to "set" or lose its elasticity, is avoided. The curve obtained by this arrangement is a double cyma. Two or more strips thus bent, when firmly secured together at their ends, will work freely without any tendency to "buckle" or interfere with each other. The whole arrangement of this engine was very neat. It drove the work attached to it very steadily, and attracted considerable attention. A distinctive feature of this engine was the method of transmitting power from it to the shafting. To render the engine compact, the fly-wheel was made very narrow, and, instead of being made to carry an ordinary flat belt, it had a V-shaped groove, receiving an angular belt, made by Mr. Charles Underhill, of Tolland, Conn. This driving-band, of which a short length is shown in the engraving, is made of leather, and is of ▽-section, the inner or thin edge being notched, as shown, the layers of leather on the broad side of the ▽ only being continuous.

The belt is thus made perfectly flexible. This driving-belt may, perhaps, be better described as a narrow belt having fixed to its inner side a number of teeth built up of thicknesses of leather, and of ▽-shaped cross-section. The pulley on the shafting was grooved like the fly-wheel, and the belt, being griped by the grooves, was run very slack without slipping. The strain on shafting and bearings was thus reduced to a very important extent. This band could be lengthened or shortened as readily as an ordinary belt. This arrangement of driving-gear is one which may probably often do good service.

44. A three-cylinder engine, exhibited by Messrs. BROTHEHOOD & HARDINGHAM, of London, attracted some attention from engineers. In this engine the cylinders are single-acting, and arranged with their axes making angles with each other of 120°. The pistons are coupled to a single crank. The large fly-wheel commonly used is dispensed with, and the crank and the connecting-rods are completely hidden by the casing of the engine in a manner quite similar to that adopted with the steam-engine well known in this country as Hicks's four-cylinder engine. The cylinders and the central casing containing the crank and connections are cast in one piece. The shaft passes out at each end through bonnets, which are carefully fitted and bolted in place.

The regulator is attached to one end of the shaft, its spindle being horizontal. It thus makes the same number of revolutions as the crank-shaft. This is sometimes three hundred revolutions per minute, and it has been stated that the unloaded engine has been driven nearly two thousand revolutions per minute without a serious jar. The valve is a revolving valve somewhat similar to those which have been long in use on the freight-steamers of the Neptune Line, plying between New York and Providence. Its axis is coincident with that of the crank-shaft, and it is turned by a prolongation of the crank-pin.

The central chamber is the steam-chest, and the pistons thus always have steam-pressure on their "forward" faces. The valve permits steam to pass to the rear of the pistons successively, thus disturbing the existing equilibrium and producing rotation. One of the most interesting points noted in this engine was the fact that the builders have apparently succeeded in securing a satisfactorily working crank-pin without especial provision for lubrication. They state that they had at first great difficulty in keeping the pin in working order. The hot steam washed out the lubricant so quickly that it required constant attention and compelled the use of large quantities of the unguent.

They now fit the crank-pin with "brasses" of some special grade of phosphor bronze, and state that the steam itself has proven a sufficient and perfectly satisfactory lubricant, and that they now use no other.

45. The steam-engine of FRIEDRICH SIEMENS, of Dresden, Saxony, was exhibited in machinery hall, and attracted attention rather because of its novelty than as promising to become practically useful. In this machine there were no valves, piston, or moving parts. The steam-boiler itself revolves, and from it power is transmitted to the machinery to be driven. It consists of a steam-boiler of approximately cylindrical form, carried on an inclined axis about which it rotates. Inside this boiler is a worm or screw composed of sheet-metal, and having such form that each portion of the screw having a length equal to its pitch, closely resembles a funnel which has been slit down one side and slightly separated to unite with others above and below it.

The lower portion of the boiler has a double bottom, and the upper is surrounded by a spiral of gas-pipe, having a direction the reverse of the funnel-like spiral below.

Water is placed in the lower portion of the boiler and in the space between it and the external jacket, a communication being established between them by means of small holes.

Surrounding the whole lower portion of the apparatus is a jacket ot non-conducting material, and between it and the boiler is a space through which circulate the gases from the furnace, or, in this case, from the gas-burner by which it is heated, passing off by a small chimney at its upper end.

A fusible plug at the top insures safety against injury by overheating.

The motion of the boiler, when revolving, is transmitted to the shafting by means of a neat device of recent introduction, a spiral coil of steel ribbon, which makes an excellent universal joint.

The heat being applied, steam is formed, which rises through the water, impinging on the immersed funnel-like spirals, producing a tendency to rotation. Above the water it enters the helix of gas-pipe, and, condensing, flows back into the boiler, its reaction causing further effort to rotate the boiler. In the small machine exhibited the motion was moderately rapid; but it evidently has little power, and the machine can hardly be considered a motor. It is interesting as a simple and ingeniously-devised apparatus and as suggesting possibly useful application where very little power is needed and where its entire freedom from noise and from the inconveniencies attending all ordinary mechanism are important desiderata.

The boiler being once filled, requires no further attention, as there is no loss of the liquid.

46. RÉSUMÉ.—Among all the stationary engines, of which class nearly a hundred were on exhibition, there were no others which call for

special mention. By far too large a number were of a quality which should not be imitated, and of the remainder the best examples were usually copies of types well known in this country, and often they were careful imitations. As a rule, attempts at improvement resulted in producing the reverse effect.

It will be seen from what has been above stated that the principles governing the economical use of steam are becoming more thoroughly studied and more generally recognized by European constructors, and that they are learning gradually how to embody those principles in their practice.

The continental manufacturers generally are still behind their British and American competitors, but by imitation of good standard designs, and by the importation in some cases of British mechanics, they are introducing into their establishments a knowledge of good design and of good workmanship, which promises at an early day to place them fairly by the side of the Anglo-Saxon, who has hitherto always exhibited decidedly higher constructive power. In the character of the raw material from which their skilled mechanic is produced, the advantage is certainly upon the side of the latter.

A peculiar gratification was found in witnessing the progress made by Austria in this direction. Her people seem to have more of the natural constructive talent than many other nations of Europe, and it only requires an intelligent and systematical training to secure its most satisfactory development.

The progressive and enterprising spirit which has been exhibited in the enterprise which brought together the collections of the *Weltausstellung* is certain to secure complete recompense by giving this talent an opportunity for the study of good examples, and by thus securing its most effective stimulus.

47. Reviewing the whole field, it may be stated that the practice of the best constructors of first-class stationary engines in the United States is still in advance of those of other countries. Foreign builders are, however, rapidly placing themselves beside us in this field. In some cases, especially in that of Great Britain, the same conservative but thorough-going spirit which has retarded the introduction of our designs is at work stimulating builders to the use of better material and of more perfect workmanship than the majority of our people are accustomed to adopt, and we shall soon find them in advance of us in our own field, should our steam-engine builders generally neglect to look as carefully to the quality of their work as do our best-known firms of tool-makers.

The advance in this direction which has occurred recently in the United States is, however, the best evidence that a market can be found for good work, and that our mechanics have learned that they may safely do such work and that they purpose doing it.

Accompanying is a tabular exhibit of the number, character, and dimensions of the stationary engines exhibited :*

48. A German engineer, T. Rittershaus, an assistant at the Royal *Gewerbe Academie*, at Berlin, in his report published since these remarks were written, makes the following introductory observations: †

"In scarcely any direction does the machinery hall at the Vienna Universal Exposition offer so much that is new and remarkable as among the prime movers, especially in steam-engines and in motors for small industries.

"Principally with reference to stationary engines, a complete change of the principles of construction is to be noted, and *we owe this mainly to the influence of the American Corliss.*

"Formerly, the regulator generally acted upon a throttle-valve, so that the tension of the steam was decreased by the diminution of space in the pipe, and the consequent increase of resistance before entering the valve-chest, and only a few systems (Farcot, Myer, and Dingler) allowed the regulator to act upon the valve-gearing itself, varying the expansion. Since the introduction of the Corliss engine, especially since the last Paris Exposition, when it attracted general attention, this has been changed so completely that to-day regulation by means of the throttle-valve, at least for machines of any importance, may be considered as a thing of the past.

"But not only does the valve-gearing of modern steam-engines indicate the influence of the Corliss engine, but also its external form and arrangement have become typical.

"Steam-engines, at present, are principally horizontal, and in the greater number of cases condensing-engines. But, instead of the bedplate which was formerly in such favor, we meet almost everywhere that American frame with its solid cast brace which has been adopted by Corliss, and which is constructed so as to resist in the best manner possible all tensile and compressive strains between the cylinder and the foundation of the fly-wheel.

"With reference to the valve-gearing, practice is not so uniform. All important engines have expansion-gearing, adjusted by the regulator, but, with regard to the manner in which they are so adjusted, their construction varies considerably. Nevertheless, they can all be classified in five main groups.

"The first of these five groups closely resembles the Corliss engine. The ideas underlying the essential parts are common to both, such as, for example, opening the parts by the engine, closing them, after disengagement by the regulator, with the assistance of an exterior force, which has been generated in an auxiliary agent (such as a weight, a spring, the tension of steam) during the opening; furthermore, the

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* London Engineering, October 17, 1873.

† *Amtlicher Bericht über die Wiener Welt-Ausstellung im Jahre* 1873; *Band II Heft* 1; *Motoren, etc.* T. Rittershaus.

47. TABLE GIVING PRINCIPAL DIMENSIONS OF AMERICAN, ENGLISH, FRENCH, BELGIAN, SWISS, AND GERMAN STATIONARY ENGINES AT THE VIENNA EXHIBITION.

Reference number.	Maker's name and country.	Locality of factory.	Type.	Whether condensing.	CYLINDERS.		Whether steam-jacketed or not.	Whether steam passes through jacket on its way to valves, or whether there is a separate valve for the jacket.	Valves	Valve-gear.	Whether expansion is controlled by governor.	Range of expansion.	Ordinary cut-off.	Working-pressure in pounds per sq. inch above atmosphere.	Revolutions per minute.	Piston speed in ft. per minute.	Governor.	AIR-PUMP.			Feed-heater.	Remarks.
					Diameter.	Stroke.												Diameter.	Stroke.	Single or double acting.		
	AMERICA.				*Inches.*	*Ft. in.*												*Inches.*	*Inches.*			
1	Norwalk Iron-Works	South Norwalk, Conn	Horizontal direct-acting	No..	12	2 0	No..		Piston-valve	Ordinary, without expansion	No	Invariable cut-off. .6	.6	75	100	400	Pickering	None..			None..	
2	Pickering & Davis	Portland, Conn	Horizontal direct-acting double cylinder-rods.	No..	6	1 0	No		Slide; no expansion-valve	....do	No	.75	.75	75	150	300	....do	None..			None..	
3	New York Safety Steam-Power Co	New York	Vertical inverted	No..	7	0 9	No..		Piston-valve	....do	No	.75	.75	75	160	240	....do	None..			None..	
4	....do	....do	....do	No..	4	0 6	No..		Slide; no expansion-valve	....do	No	.75	.75	75	200	200	....do	None..			None..	
	GREAT BRITAIN.																					
5	W. and J. Galloway & Sons	Manchester	Horizontal direct-acting compound	Yes	14 in. & 24 in.	2 6	No..		Slides; separate induction and eduction for low-pressure cylinder	Crank for high-pressure slide, with connection to govern eccentric for low-pressure slides.	High-pressure cylinder valve only.	.2 to .5	0.3	60	60	300	Weighted with a disk.	8	30	Double..	None..	Cranks at 180 degrees.
6	Reading Iron-Works Company, (limited)	Reading	Horizontal direct-acting	Yes	17	2 6	Yes	Separate valve	Ordinary	Ordinary	No	.07 to .66	.1	60	70	350	Ordinary	5½	30	Double..	None..	
7	....do	....do	....do	No..	10	1 2	Yes	....do	....do	....do	No..	.14 to .64	.33	50	100	233	.... do	None..			None..	With other smaller engines by same firm in agricultural hall; not at work.
8	J. Derham	Blackburn	....do	No..	16	3 0	Yes	Slide chest communicates with jacket.	Double slides and short ports; ordinary expansion on back.	.... do	No	.1 to .4	.3	75	55	330	Porter	None..			Yes..	Air-pump and condenser not attached for want of room.
9	....do	....do	....do	Yes	18	3 0	Yes.	....do	Cross gridiron expansion-slides	Cross slides worked by cams and spur-gearing.	Yes	.0 to .7	.4	75	55	330	Ordinary	7	36	Double..	Yes ..	
10	Tangye Brothers & Holman	London	....do	No	12	2 0	Yes	....do	Ordinary	Ordinary	No	.1 to .9	.25	50	60	240	Tangye	None..			None..	
11	Clayton & Shuttleworth	Lincoln	....do	No..	13	1 6	Yes	Separate valve	Ordinary expansion-valves not adjustable while running.	.... do	No	.05 to 1.0	.25	60	85	255	Ordinary	None..			Yes...	In agricultural hall; not at work.
12	Marshall Sons & Co., (limited)	Gainsborough	....do	No.	10¾	1 2	Yes	Direct	....do	....do	No	.25 to .625	.25	60	110	256	....do	None..			Yes ..	In agricultural hall;; not at work, and also a combined engine.
13	Charles Powis & Co	London	Horizontal direct acting double cylinder.	No..	10½	1 6	Yes	Slide chest communicates with jacket.	Ordinary invariable expansion	....do	No		.5	50	90	270	....do	None..			None..	
14	D. New & Co	Nottingham	Horizontal direct-acting	No.	12	1 6	No..		Ordinary	... do	Yes		.25	50			Porter	None..			None..	Not at work.
15	.... do	....do	Vertical	No..	8	0 11	No.		Ordinary; no expansion-valve	... do	No			50			Ordinary	None..			None..	Also another smaller vertical; neither at work.
16	Robey & Co., (limited)	Lincoln	Horizontal direct-acting	No..	9¼	1 2	No..		....do	....do	No	.125 to .75	.3	50	125	291	....do	None..			None..	In agricultural hall, and also a combined engine; neither at work.
17	Ruston & Proctor	....do	....do	No..	8¼	1 0	Yes	Direct	Ordinary	.... do	No	.0 to .625	.3	60	120	240	Parabolic	None..			None..	Vaughan and Stubb's ejector on jacket; also a combined engine: neither at work.
18	E. and F. Turner	Ipswich	....do	No..	6	0 10	Yes	Separate pipe	Single slide only	Eccentric, shifted by Hartnell and Guthrie's governor.	Yes	.0 to .625	.3	60	270	450	Hartnell and Guthrie	None..			None..	No bed-plate wrought-iron side-frames, &c.; not at work.
19	Brotherhood & Hardingham	London	Patent three-cylindered engine	No.	9	0 8	No..		Rotary slide-valve	None	No		Abt. .75	60	225	300	On-crank-shaft	None..			None..	Specially adapted for high speeds; one also at work driving a "helical" pump.
	FRANCE.				*mm.* *in.*	*mm.* *in.*																
20	Fives-Lille Cie. de	Fives-Lille	Horizontal double-acting	No..	350 13.77	700 27.55	No..		Ordinary	Ordinary	No	.1 to .5	.3	75	50	230	Ordinary	None..			None..	
21	Schneider et Cie	Creuzot	Vertical inverted compound	Yes	250 9.84 400 15.75	600 23.6	Yes	Between the two cylinders.	....do	....do	No	.1 to .3	0.5	75	60	236	Schneider's patent	None..			......	Not at work.
	BELGIUM.																					
22	Bede et Cie., (Société Houget Teston)	Verviers	Horizontal direct-acting	Yes	450 17.71	1000 39.37	Yes	Valve-chest communicates with jacket.	Corliss	Bede and Farcot's patent	Yes	.0 to .75	.25	60	45	295	Proell	8.85	39.37	Double..	None.	
	SWITZERLAND.																					
23	Gebrüder Sulzer	Winterthur	... do	Yes	.. .. 17.72	...... 41.37	Yes	....do	Equilibrium double beat	Sulzer's patent	Yes	.0 to .7	.15	75	50	344	Porter	7.09	41.37	Double..	None..	
24	....do	.... do	....do	No.	200 7.87	500 19.68	Yes	....do	Rider's (semi-cylindrical) expansion-valve on back of slide.	Ordinary	Yes	.0 to .7	.15	75	85	278	....do	None..			None..	Air-pump and condenser can be fitted to this engine, and a similar smaller one at option.
25	Escher und Wyss.	Zurich	....do	No..	700 27.55	1350 53.15	Yes	Separate valves	Corliss	Spencer and Inglis's	Yes.	.0 to .75	.15	75	35	310	....do	None..			None..	Not at work.
26	Socin und Wick	Basel	....do	No	330 12.99	750 29.52	Yes	....do	....do	....do	Yes	.0 to .75	.125	70	65	320	....do	None..			None..	Not at work.
27	Scheller und Berchtold	Thalweil, Zurich	....do	Yes	300 11.8	600 23.62	Yes	....do	Disks, (Berchtold's patent)	Berchtold's patent	Yes	.0 to .4	.15	75 to 105	65	256	Ordinary, with weight	6.29	11.8	Double..	None..	
	GERMAN EMPIRE.																					
28	Sächsische Maschinen Fabrik zu Chemnitz, vor Richard Hartmann.	Chemnitz	....do	No	680 26.77	1300 51.18	Yes	Jacket communicates with valve-chest.	Double-beat equilibrium	Eccentrics on a countershaft, somewhat resembling Sulzer gear.	Yes	.0 to .8	.25	75	38	324	Porter	None..			None..	Not at work.
29	Maschinen Fabrik Augsburg	Augsburg	....do	Yes	345 13.58	740 29.13	Yes	....do	....do	Sulzer	Yes	.1 to .75	.2	90	62	300	Ordinary				None..	Not at work.
30	Gräflich Stolberg Wernigerödische Faktorei	Ilsenburg, Harz	....do	Yes	400 15.74	800 31.49	No..		Corliss	Corliss	Yes	.1 to .3	.3	60	50	262	Buss			Double..	......	
31	C. Reinecke	Königsburg	....do	Yes	..... 17.0	..... 33.0	No..		....do	....do	Yes	.0 to .75	.15	60	45	247	....do				None..	In pavilion with German ice-machines, &c.
32	Görlitzer Maschinenbau Anstalt und Eisengiesserei Actien-Gesellschaft	Görlitz	Horizontal direct-acting compound	Yes	310 12.20 580 22.83	800 31.49	No..		Ordinary	Ordinary	H. P. cylinder valve only.	.1 to .9	.125	75	60	314	Ordinary	6.69	31.49	Double..	Yes...	Both cylinders connected to one crank; not at work.
33	Actien Gesellschaft der Holler'schen Carlshütte.	Carlshütte, nr. Rendsburg.	Horizontal direct-acting double cylinder.	No.	460 18.11	840 33.07	No..		....do	....do	No	.125 to .875	.33	60	45	247	Ordinary, with weight	None..			Yes...	The feed-heater is not attached permanently to engine.
34	Gebrüder Decker	Canstatt	Horizontal direct-acting	Yes	400 15.74	800 31.49	Yes	Separate valve	Krausse's expansion-valve on back of slide.	....do	Yes	.05 to .75	.16	80	54	283	Porter	6.29	31.49	Double..	None..	Can work at any pressure not exceeding 150 pounds per square inch: not in motion.
35	Sächsische Dampfschiffs und Maschinenbau Anstalt	Dresden	....do	No..	300 11.81	600 23.62	No..		Improved Forcot's expansion-valve	....do	Yes	.0 to 1.0	.33	60	52	204	Approximate parabolic	None..			None..	Also combined engine; neither at work.
36	Berliner Union Actien Gesellschaft für Eisengiesserei, &c., (vor. Webers.)	Berlin	....do	No..	370 14.57	710 27.95	.....	Jacket communicates with valve-chest.	Ordinary	Eccentrics and patent gear for governor control.	Yes	.0 to .75	0.125	75	55	256	Werner	None..			None..	Not at work.
37	Englerth und Cünzer	Eschweiler Aue	....do	No.	.. 24.81	...... 31.5	No.		....do	Ordinary	No	.1 to .75	.3	75	50	262	None	None..			None..	Not at work; for rolling-mill.
38	Maschinenbau Verein zu Chemnitz	Chemnitz	....do	No	354 13.93	732 28.81	No..		Ordinary; no expansion-valve	Link-motion	No			75	44	211	None	None..			None..	Not at work; for rolling mill.
39	Chemnitzer Maschinenbau Gesellschaft, (vormals Münnich.)	....do	....do	No.	470 18.5	850 33.46	No..		Ordinary	Ordinary	No	.125 to .875	.25	60	40	223	Porter	None..			None..	In eastern agricultural hall: not at work.
40	Dingler'sche Maschinen Fabrik	Zweibrücken	Horizontal direct-acting compound	Yes	125 4.92 250 9.84	500 19.68	Yes	Jacket, high-pressure cylinder only, communicates with valve-chest.	Conical revolving	Valves driven from crank shaft by screw-wheels.	High-pressure cylinder valves only.	.05 to .6	.125	150	115	377	....do	4.92	7.08	Double..	Yes...	Cranks at 180°. The valves and gear are on Ehrhardt's system.
41	Deutsch-Englisch Company.	Hanover	Horizontal direct-acting double cylinder.	No	...... 9.0	..... 14.0	No..		Ordinary; no expansion-valve	Ordinary	No		.75	60	110	255	....do	None..			None..	With another engine by same makers in eastern agricultural hall: not at work.
42	Adler und Panovsky	Paulshütte, Soran	Horizontal direct-acting	No..	..... 11.22	..... 22.4	No..		Ordinary	....do	No	.125 to .1	.3	75	60	224	Ordinary	None..			None..	Not at work.
43	Hermann Ulbricht	Chemnitz	....do	No.	..... 11.22	..... 22.4	No..		....do	....do	No	.0 to .1	.25	75	60	224	....do	None..			None..	Not at work.

NOTE.—"Ordinary," in the column headed "Valves," is to be understood to mean slide-valves with expansion valves on back, variable while the engine is running, unless the contrary be stated. All the engines described in this table are in motion, except those marked "Not at work."

separation of the parts in order to diminish the dead-space and to prevent the loss of heat by alternate contact of the same surface with fresh and waste steam ; and finally, the separate valve-gearing for the entering and the exhaust steam.

"I would like to class this whole group under the name of 'Corliss engines,' although some of them, such as the Sulzer engine, the engine built by Scheller & Berchtold, &c., differ from it in construction, not only with reference to the external, but also with reference to the internal valve-gearing. Some of them have already attained a considerable celebrity.

"A second group is based upon the older Farcot valve-gearing, which is, however, considerably changed, on account of the greater expansion and its variation between wider limits.

"The third group has adopted Meyer's valve-gearing, this being made to depend upon the regulator in various ways.

"Still another large group is formed by those engines in which the regulator varies the eccentricity, or the lead, of the expansion-gearing eccentric, or both at the same time.

"As belonging to this group, I also consider those engines in which the length of the stroke of the valve is varied by changing the point of application at the valve-rod by means of a connecting-link, instead of varying the eccentricity.

"The fifth and last group, finally, is formed by two engines with a peculiar stop-cock valve-gearing, in which the expansion is varied by a special expansion-valve, *i. e.*, by a second cock whose position with reference to the valve depends upon the regulator."

CHAPTER II.

MARINE STEAM-ENGINES.

CHARACTER OF EXHIBITS; HISTORICAL SKETCH OF MARINE-ENGINE PRACTICE; INCREASE OF STEAM-PRESSURE; SURFACE-CONDENSATION; RECENT CHANGES; CONDITIONS OF MAXIMUM EFFECTIVE EXPANSION; CAUSES OF THE SUCCESS OF THE DOUBLE-CYLINDER ENGINE; COMPOUND MARINE ENGINE OF BURMEISTER & WAIN; STEAMERS OF THE DONAU DAMPFSCHIFFAHRT GESELLSCHAFT; PRINCIPLES OF ECONOMY OF PROPULSION BY PADDLE-WHEELS AND CHAIN-TOWAGE; ENGINES OF THE DONAU GESELLSCHAFT, OF THE STABILIMENTO TECHNICO TRIESTINO; HER BRITANNIC MAJESTY'S IRON-CLADS MINOTAUR AND BELLEROPHON; OSCILLATING ENGINES OF THE SOCIÉTÉ JOHN COCKERILL; THE FEATHERING PADDLE-WHEEL; THE AMERICAN STEAM-ENGINE; THE MOTALA WORKS; SWEDISH TWIN-SCREW VESSELS; MOTALA PASSENGER-STEAMER.

49. CHARACTER OF EXHIBITS.—The exhibition of marine engines was not remarkable, either for the number of exhibits or for the variety and novelty of designs, although it was probably quite as good as should be expected under the circumstances. But little is to be gained by the study of this class of exhibits at Vienna, either in respect to the direction of progress in design or in respect to the character of material and of workmanship to be observed.

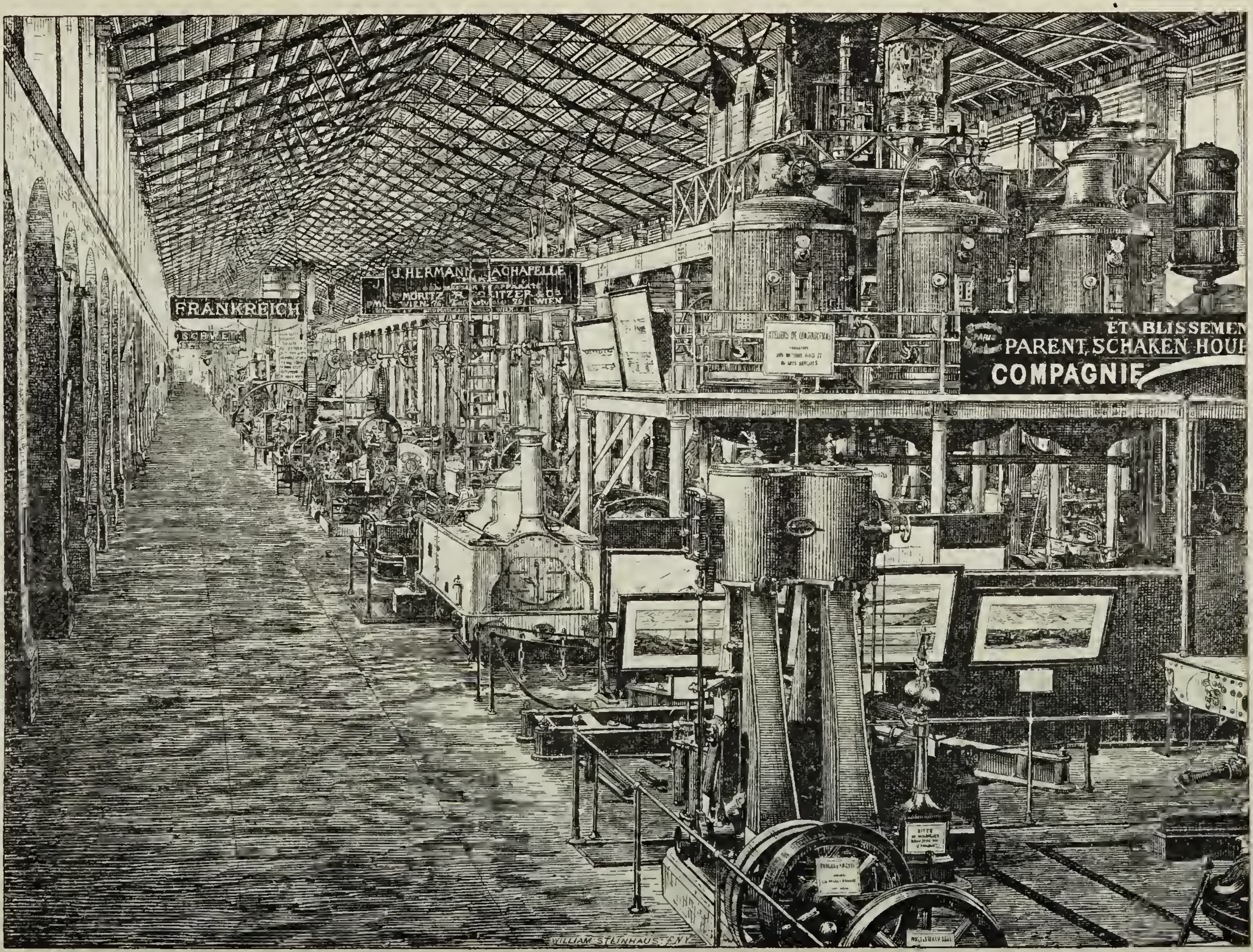
The collection is, however, interesting as exhibiting illustrations of every stage of the progress of the modern revolution which has brought the "compound" engine into general use as a marine engine.

50. HISTORY OF MARINE-ENGINE PRACTICE.—Nearly three-quarters of a century ago this form of engine was brought into the market as a rival of the Watt engine, the use of which was then rapidly extending, driving from the field the ruder machines of Newcomen and Beighton. The time for the success of the former had not, however, then arrived. The principles already stated as the practical bases of the economical success of the steam-engine were not then recognized or understood. Steam was generally carried at very nearly atmospheric pressure; piston-speed was extremely low, and the benefit of the steam-jacket was then, and long after, a subject of dispute.

The double-cylinder engine, therefore, failed entirely to compete with the single-cylinder, and, although occasional attempts were made to bring it up again, it has only within a comparatively short space of time succeeded in holding its own by fair competition with the other style.

As steam-pressures have risen and piston-speeds have become greater, the range of economical expansion has increased at sea, as on land, and,

Vienna Exhibition 1873. Machinery etc.



American Photo Lithographic Co N.Y. (Osborne's Process.)

Fig. 22

with the demand for the maximum economy of fuel obtainable, has risen the necessity of substituting the compound engine with its divided expansion for the single-cylinder engine with its irregular strains.

The advantage of introducing double engines at sea is considerably greater than on land.

The coal carried by a steam-vessel is not only an item of great importance in consequence of its first cost, but, displacing its weight or bulk of freight which might otherwise be carried, it represents so much non-paying cargo, and is to be charged with the full cost of transportation in addition to first cost. The best of steam-coal is therefore usually chosen for steamers making long voyages, and the necessity of obtaining the most economical engines is at once seen, and is fully appreciated by steamship proprietors.

Again, an economy of one-fourth of a pound per horse-power per hour gives, on a large transatlantic steamer, a saving of about one hundred tons of coal for a single voyage. To this saving of cost is to be added the gain in wages and sustenance of the labor required to handle that coal, and the gain by one hundred tons of freight carried in place of the coal.

The progress of improvement has been somewhat slow and is easily traced. In the early days of steam-navigation many types of single-cylinder steam-engines were tried, and even, as already stated, occasionally a compound engine. European practice gradually settled down to the adoption of the "side-lever engines" for marine purposes on sea-going steamers. In America the overhead "beam-engine" came into almost universal use in eastern waters, and the direct-acting engine as universally on western rivers. The latter engine has nearly always been made non-condensing. Engines for sea-going steamers have been invariably condensing.

The propelling-instrument was always, until very recently, the paddle-wheel. Watt patented a "spiral oar" in 1784, and Bernouilli seems to have had the idea a quarter of a century earlier. Col. John Stevens, of Hoboken, N. J., built a boat and steam-engine with a single screw, and a second with twin screws, and worked them successfully with steam at 50 pounds' pressure from a tubular boiler, in the years 1804 and 1805.* The plans of these vessels were matured at about the time that Fulton was proposing to order from the English manufacturers the Boulton & Watt engine, which he afterward used to drive the Clermont.

The next boat of Colonel Stevens, the Phœnix, was completed almost simultaneously with Fulton's boat. Paddle-wheels were used instead of the screw, because the size of the boat was too great to permit the economical use of screws in such shallow waters.

The use of the paddle became universal, and it remained the only propelling-instrument used for very many years.

51. The rude workmanship and the faulty design of the machinery of

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*This machinery is preserved at the Stevens Institute of Technology at Hoboken.

those early days made it impossible to detect faults of detail, and progress was necessarily extremely slow. With gradual improvement in tools and in methods of doing work, it became possible to control higher steam and to work it successfully; and the change in this direction has been steadily going on up to the present time with all types of steam-engine. At sea this rise of pressure was for a considerable time retarded by the serious difficulty encountered in the tendency of the sulphate of lime to deposit in the boiler. When steam-pressure had risen to 25 pounds per square inch, it was found that no amount of "blowing out" would prevent the deposition of seriously large quantities of this salt, while at the lower pressures at first carried at sea no troublesome precipitation occurred, and the only precaution necessary was to blow out sufficient brine to prevent the precipitation of common salt from a supersaturated solution.

52. SURFACE-CONDENSATION.—The introduction of surface-condensation was promptly attempted as the remedy for this evil, but for many years it was extremely doubtful whether its disadvantages were not greater than its advantages. It was found very difficult to keep the condensers tight, and boilers were injured by some singular process of corrosion, evidently due to the presence of the surface-condenser. The simple expedient of permitting a very thin scale to form in the boiler was, after a time, hit upon as a means of overcoming this difficulty, and thenceforward the greatest obstacle to the general introduction was the conservative disposition found among those who had charge of marine machinery, which conservatism regarded with suspicion every innovation. Another trouble arose from the difficulty of finding men neither too indolent nor too ignorant to take charge of the new condenser, which, more complicated and more readily disarranged than the old, demanded a higher class of attendants.

Once introduced, however, the surface-condenser removed the obstacle to further elevation of steam-pressure, and the rise from 20 to 60 pounds' pressure soon occurred.

The writer had occasion in the year 1867, when an engineer-officer in the Navy, to investigate the causes and to determine how to prevent the corrosion frequently attendant upon surface-condensation, and a paper embodying his conclusions was written in November of that year for the Association of Assistant Engineers of the United States Navy at the Naval Academy, where he was then detailed to duty as an acting assistant professor of natural and experimental philosophy.

This action is ascribed by some engineers to a galvanic action induced by the large amount of copper or of bronze entering into the construction of the surface-condenser; by others, it is supposed to be due to the action of impurities retained in the feed-water; still others consider it the effect of the corrosive action of certain vegetable acids derived from the oils or tallow used in lubrication, and some refer it to what the writer believes at least one cause—the action of metals transported mechanically in suspension, or in solution as a metallic salt, from the condenser to the boiler.

Engineers generally admit that experiment has not yet satisfactorily answered this important question, and often, without knowing anything of the cause, they take the only well-tested method of preventing the effect, viz, covering interior heating-surfaces with a coating of scale, and seldom make an investigation of the phenomenon with a view to the determination of its cause.

Although observation and experiment have not pointed with certainty to the cause of this "pitting," as it is generally and expressively termed, a careful consideration of known facts and chemical laws may enable us to frame a theory that shall at least possess the merit of accordance with observed facts and of strong probability.

Cases have occurred, and instances are perhaps known to every engineer, in which, after engines and boilers had been working a considerable length of time with jet-condensers, and while the latter were still in good condition, surface-condensers were introduced and a rapid and ruinous corrosion of the boilers immediately ensued. This effect could not have been due to the simple change within the boiler from salt-water to fresh, for such corrosion is not observed in land-boilers using good water. It is also well known that pure water is less active in attacking the metals than water containing salts.

It is extremely improbable that such rapid corrosion and pitting could be due to a galvanic action in a circuit in which the interior of the boiler forms one pole and the bronze of the condenser and pumps forms the other.

That galvanic action may take place to some extent is not unlikely; for the cases so often reported in which the iron of the condenser and hot-well, in arrangements of jet-condenser, is destroyed by oxidation, or, as it is often described by the ignorant, by transmutation into plumbago, are probably due principally to such action; and, while the distance of the boiler from the electro-negative metals protects it very greatly, it probably cannot completely prevent corrosion from this cause.

But that this action must be very slight seems proved by the fact that internal corrosion from all causes is usually inappreciable with jet-condensers, even where external corrosion has partly injured the boiler, although the presence of the copper or bronze, which acts with such serious results on the metal of the condenser and the air-pump in its vicinity, might be expected in such cases to affect the boiler also quite seriously before the lapse of any considerable period of time.

It should also be remarked that "pitting" is not more frequently developed at the points nearest the connections with the engines than elsewhere, as might be expected to be the case were it an effect of galvanic action induced by parts of the engine. Further, if it were possible for galvanic action to produce extensive corrosion, it would still probably take place with tolerable uniformity over the surface as it takes place in the galvanic battery, and as it generally takes place in the oxidized condensers before referred to. It probably would not produce the deep and irregularly-distributed depressions found to accompany surface-condensation.

The addition, therefore, of bronze even to the extent that it is introduced in the surface-condenser does not appear likely to induce serious galvanic action on the boiler.

The necessary conclusion seems to be that the peculiar corrosion under consideration must be caused by some foreign matter carried into the boiler by the feed-water, either in mechanical suspension or in solution.

An analysis made by the writer in 1865 proved the brown deposit above the water-line of a boiler used in connection with a surface-condenser to consist of oxide of iron without a trace of other matter except earth; but an English analysis of the brown, slimy deposit found *upon the pitted surfaces* showed that it consisted of oxide of iron with about one per cent. each of *grease* and of *oxide of copper.*

If, as will presently be shown to be probable, the copper is deposited on the surface of the iron in intimate contact with the metal and in crevices and depressions, the amount given is probably far too small.

The presence of grease bears strongly against the theory which supposes the lubricants carried into the boiler to be decomposed, by high temperature, into the fatty acids which attack the iron. Could such decomposition take place, it is very probable that the iron would be attacked, forming an insoluble soap. But, even then, it is questionable whether such feeble acids as are the fatty acids would not produce a far less violent, as well as a more diffused, action.

Such decomposition of oils cannot, however, take place at the temperatures and pressures of our marine steam-boilers, as it requires a temperature of from 450° to 500° to decompose the oils even when not under pressure, and under pressure still higher temperatures are required.

Consequently the only change that may be anticipated in the lubricants is that which takes place in air, *i. e.*, its slow oxidation and final decomposition into carburetted hydrogens and oxides of carbon.

The only other matters carried into the boiler by the feed-water are organic matters and copper and oxide of iron.

From the first and the last no serious effect is to be apprehended, while from the copper, which analysis shows to exist in the boiler in all such cases, must be expected most injurious action.

There are three ways in which copper may be carried into the boiler:

1st. Mechanically by the current of feed-water in the form either of metal or of oxide; most probably the latter.

2d. Dissolved in the water as a metallic salt.

3d. Dissolved as oxide in the oil or tallow.

Neither copper nor its oxide is soluble in water, and as a salt of copper once formed would not by contact with iron be reduced to oxide, it is very possible that part of the oxide formed by analysis may be carried in suspension by the water, as gold and other heavy metals are known to be transported by a current.

The formation of the oxide would take place very readily by contact of bronze in presence of hot water with the air passing with the water through the engine. Its transportation to the boiler might not at first seem probable, but when it is considered that under such circumstances it takes the form of a flocculent mass of extreme levity, such transportation will not be considered improbable.

The only salt of copper that can probably be carried over in solution is the chloride, which is derived by a peculiar, and as yet unstudied, reaction.

When sea-water containing organic matter is brought in contact with oxide of copper, the organic substance takes from the copper its oxygen, and the metal appears then to form with salt a double chloride of copper and sodium by an unknown reaction.

This is a soluble salt, which is carried to the boiler, when by another double decomposition the copper is deposited.

In the main engine the organic matter is introduced as oil, and is found as an impurity in the water or is derived from the packing. The reaction referred to above is not described in any published work, and its exact formula cannot be stated.

Finally the oxide of copper is carried to the boiler dissolved in the oil and tallow used for lubrication, and very probably it may be principally by such solution that the deposit of copper is produced.

The salts of copper entering the boiler in these several ways, swept about in impalpable particles by the circulation of water, are finally lodged in the depressions and minute crevices in the surface of the iron of the boiler, and at every point at which it collects the iron is rapidly corroded and a depression or "pit" produced.

The probable cause of the corrosion accompanying surface condensation is principally copper carried over from the condenser as an oxide dissolved in oily matter or as a chloride in solution in the feed-water, and this action is assisted by addition of exceedingly small quantities of copper carried over in mechanical suspension, and is also stimulated by very slight galvanic action induced directly by the voltaic relations between the copper of the condenser and the iron of the boiler and between different portions of iron in different states of aggregation. All of these causes are far more energetic with the surface than with the jet-condenser, and together may cause very rapid corrosion.

As a particle of copper will induce voltaic action over a surface of many times its own area, but small quantities of copper in actual contact with the iron may produce very serious corrosion; and it may be readily believed that the amount carried into the boiler from a surface-condenser may be in a few months sufficient to produce marked effects.

The action being local, the distribution of pieces of zinc in the boiler cannot be expected to effect a cure, although it would probably have the effect of checking corrosion.

The proper remedy would seem to lie either in the substitution of some other metal for the copper or in covering the surfaces, either of the iron or the copper, by a substance that may not act injuriously upon the more oxidizable metal.

The latter method is the one universally adopted. In most cases the heating-surfaces are allowed to become slightly coated with scale, and manufacturers are also adopting the practice of tinning the condenser-tubes.

53. RECENT CHANGES.—Meantime the improvements in design and in workmanship had so far perfected the then standard marine engine in its details that the advantages of the screw became perceivable, and it began to displace the paddle-wheel.

The change from the side-lever single-cylinder engine, with jet-condenser and paddle-wheels, to the direct-acting compound engine, with surface-condenser and screw-propellers, has occurred within the memory and under the observation of even young engineers, and it may be considered that the revolution has not been completely effected. This change in the design of engine is not as great as it at first seemed likely to become. It is a principle which is becoming gradually understood by engineers that, so far as simple expansion is concerned, it is not a matter of consequence whether it takes place in one cylinder or in several. In other words, as stated by Rankine, "the energy exerted by a given portion of a fluid during a given series of change of pressure and volumes depends on that series of changes, and not in the number and arrangement of the cylinders in which those changes are undergone.

"The advantage of employing the compound engine is connected with those causes which make the actual indicated work of the steam fall short of its theoretical amount, and also with the strength of the engine and its framing, the steadiness of action, and the friction of its mechanism."

54. CONDITIONS OF MAXIMUM EFFECTIVE EXPANSION.—The changes of design recently observed in marine engines, and less strikingly in stationary steam-engines, have been compelled by purely mechanical and practical considerations. The increase noted in economy of expenditure of steam and of fuel is, as has been stated, due to increased steam-pressure, greater expansion, and higher piston-speeds, with improved methods of construction and finer workmanship. These several directions of change occur simultaneously, and are all requisite. To secure maximum economy for any given steam-pressure, it is necessary to adopt a certain degree of expansion which gives maximum economy for that pressure under the existing conditions.

This point of cut-off for maximum efficiency lies nearer the beginning of the stroke as steam-pressure rises. For low pressure a much greater expansion is allowable in condensing than in non-condensing engines; but as pressure rises, this difference gradually lessens. For example, with steam at 25 pounds by gauge, the best economical results are obtained when expanding about three times in good condensing-engines and about one and a half times in non-condensing engines. With steam at 50 pounds, these figures become five and two and a half, respectively; and at 75 pounds, the highest efficiency is secured in condensing-engines cutting off at one-fifth and in non-condensing engines with cut-off at one-third stroke.

Owing to the increasing proportional losses due to back-pressure and other retarding influences, the departure from the economical result indicated for the perfect engine becomes greater and greater, until, at a pressure of between 200 and 250 pounds, the proper point of cut-off becomes about one-sixth or one-seventh, and very nearly the same for both classes of engines, and the increase of efficiency by increase of pressure and greater expansion becomes so slight as to indicate that it is very doubtful whether progress in the direction of higher pressure will be carried beyond this limit.

55. CAUSES OF THE SUCCESS OF THE DOUBLE-CYLINDER ENGINE.—But this limit cannot be even approached in the recently standard form of marine engine, that with single cylinder.

In the stationary engine a large fly-wheel is admissible, and may be relied upon to secure regularity of motion with a cut-off as short as one-fourth or one-fifth, although, even in this case, the power required to overcome the friction of its shaft becomes a tax which tells somewhat strongly against the moderate gain in the efficiency of the steam which is by its use rendered attainable. A fly-wheel has been used on board ship with a single-screw engine of the old type, and, it has been claimed, with good results. General opinion among marine engineers is, however, entirely opposed to its use, and without it, with high steam and considerable expansion, it is quite impossible to secure regularity of motion in even the usual form of two engines with cranks coupled at right angles when working so expansively as to produce a considerable range of pressure in the cylinder.

Another difficulty, which is common to all cases in which considerable expansion occurs in one cylinder, is that of the size and weight of parts which must be proportioned to carry the maximum stresses of high pressure while transmitting a mean pressure which is but a fraction of the maximum.

The engine which expands steam greatly is, therefore, necessarily a heavier engine than that which uses steam of lower pressure, obtaining the same power without expansion.

Still another objection to great expansion in the single cylinder is to be found in the fact that a large proportion of the total work is done at the beginning of the stroke, and the proportion absorbed by friction becomes an objectionably large percentage of the whole. The serious losses arising from condensation and re-evaporation within the cylinder, and which place an early limit to the benefit derivable from expansion, affect both types of engine, and, so far as seems now known, equally

Certainly no reliable determination has yet been made of the comparative effect of this action upon them.

The lightness of engine and the smaller weight of boiler required when the "compound" engine is used are great advantages, and, when coupled with the fact that by no other satisfactory device can great expansion and consequent economy of fuel be obtained at sea, the advantages are such as to make the adoption of this style of engine imperative for ship-propulsion.

The committee of the British admiralty on designs of ships of war have reported recently, "The carrying-power of ships may certainly be to some extent increased by the adoption of compound engines in Her Majesty's service. Its use has recently become very general in the mercantile marine, and the weight of evidence in favor of the large economy of fuel thereby gained is, to our minds, overwhelming and conclusive. We, therefore, beg earnestly to recommend that the use of compound engines may be generally adopted in ships of war hereafter to be constructed, and applied whenever it can be done with due regard to economy, and to the convenience of the service, to those already built." Chief Engineer Charles H. Baker, U. S. N., has collected the results of extended trials of marine engines under ordinary conditions of regular working, and they are condensed in the following table:

Relative economy of simple and compound engines.

Description of engine.	Pounds of steam consumed per hour per total horse-power, inclusive of the quantity condensed in the production of the power.	Pounds of steam condensed in the steam-jackets per total horse-power, calculated upon the basis of an experiment with the engine of the Brooklyn Water-Works.	Pounds of steam condensed in the cylinders per total horse-power, due to all causes other than the production of the power.	Cost of the power in pounds of steam per horse-power per hour.			Pounds of steam consumed per total horse-power developed in the low-pressure cylinder, inclusive of the quantity condensed in the steam-jackets.
				Total.	Indicated.	Net.	
60 x 36 inch Navy engines:							
United States steamer Guerriere	23.67	....	4.99	28.66	35.70	40.56	....
United States steamer Delaware	25.96	....	4.00	29.96	36.40	41.03	....
United States steamer California	24.50	....	5.10	29.60	35.40	41.00	....
United States steamer Congress	25.95	....	4.40	30.35	35.55	40.85	....
50 x 42 inch Navy engines:							
United States steamer Alaska	23.40	....	4.10	27.70	35.30	41.40	....
United States steamer Benicia	23.50	....	4.30	27.80	35.20	40.30	....
36 x 36 inch Navy engines:							
United States steamer Resaca	23.80	....	5.00	28.80	34.80	43.00	....
United States steamer Swatara	23.00	....	4.20	27.20	33.70	38.60	....
Compound engines:							
Steamer ———	15.9	2.18	....	18.08	22.53	27.16	29.18
Steamer Italy	16.7	2.18	....	18.88	21.49	26.10	31.57
Steamer Spain	16.6	2.16	....	18.76	21.85	26.54	32.77
Steamer City of Bristol	16.2	2.11	....	18.31	21.01	25.85	28.07
Steamer Gracia	18.3	2.32	....	20.62	21.97	26.31	....
Steamer Patagonian	15.9	2.04	....	17.94	21.16	25.99	29.42
Steamer Batavia	17.6	2.27	....	19.87	24.78	30.09	34.14
Steamer Egypt	17.7	2.28	....	19.98	24.89	29.42	32.00
Mean:							
60 x 36 inch engines	25.02	....	4.62	29.64	35.76	40.86	....
50 x 42 inch engines	23.45	....	4.20	27.75	35.25	40.85	....
36 x 36 inch engines	23.40	....	4.60	28.00	34.25	40.80	....
Mean:							
Navy engines	23.95	....	4.47	28.46	31.75	40.83	....
Compound engines	16.86	2.19	....	19.05	22.46	27.18	31.02

Builders have but slowly learned the principles stated above in reference to expansion in one or more cylinders, and the earlier engines were made with a high and low pressure cylinder working on the same connecting-rod, and each machine consisted of four steam-cylinders. It was at last discovered that a high-pressure single-cylinder engine exhausting into a separate larger low-pressure engine might give good results, and the compound engine became as simple as the type of engine which it displaced. This independence of high and low pressure engines is not in itself novel, for the plan of using the exhaust of a high-pressure engine to drive a low-pressure condensing-engine was one of the earliest of known combinations.

56. EXHIBITED MARINE ENGINES.—At the Vienna Exhibition are illustrated all of these types of engine. There are a number of marine engines of older form exhibited, but they do not call for special mention here.

An engine is exhibited by Messrs. BURMEISTER & WAIN, of Copenhagen, Denmark, which is a good example of the more cumbersome style of compound engine. A high and a low pressure cylinder are mounted in the same line, their pistons secured to the same rod and driving the same crank. (See Figs. 24 and 24 A.) The large steam-cylinders have trunks. A similar pair is coupled to the other crank, which is set at right angles with the first. This forms a four-cylinder compound engine, such as was thought good practice a few years ago. This engine is described as of thirty nominal horse-power. The builders claim that these engines will give 150 indicated horse-power with a consumption of 2½ pounds (Rhen-

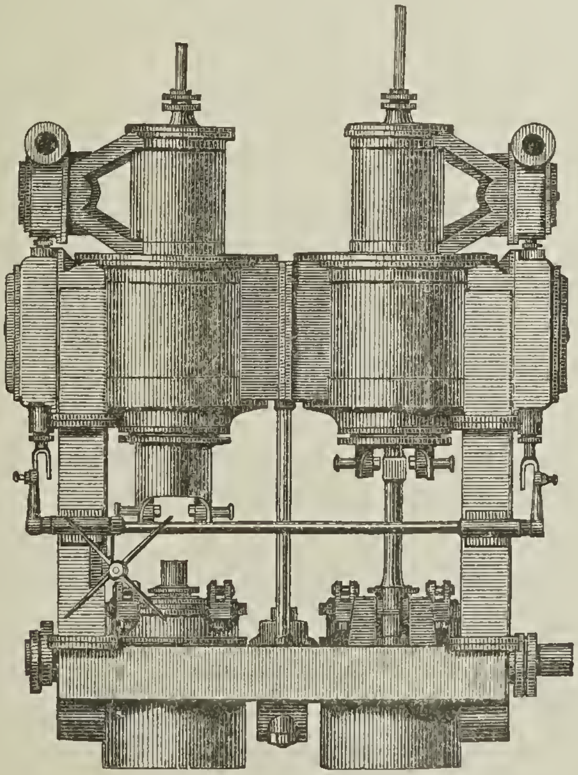

FIG. 24.—Engine of Burmeister & Wain.

ish) of coal per horse-power per hour. They are built complete with boilers, and erected on board ships, for $18,000, Danish money, ($9,900 gold.) These engines are apparently well proportioned in all details, and of good material. They have a good finish, and their workmanship throughout is excellent. The height of the engines, which would otherwise be very objectionable, has been kept within usual limits by fitting the low-pressure engines with trunks. The valves of the high-pressure cylinders are attached to the same rods which operate the valves of the larger cylinders. The engines are fitted with surface-condensers, and have bucket and plunger air-pumps, worked by levers attached to the main trunk. This firm have built these engines since about 1854, using pressure of 50 to 60 pounds per square inch. The boilers of the Fylla, built in 1861, drove a set of these engines and required no repairs until 1871–'72.

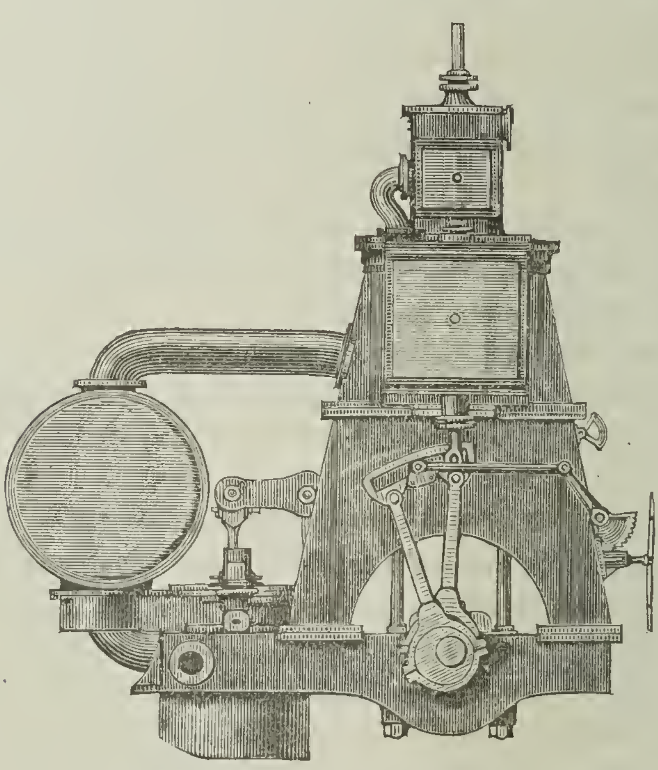

FIG. 24 A.—Engine of Burmeister & Wain.

57. The compound marine engines of the DONAU DAMPFSCHIFFAHRT GESELLSCHAFT form a very interesting collection, and the most extensive exhibit of this class on the grounds. This company had a small building appropriated to its exhibits, and filled it with a very fine set of model steamers, and with engines of full size, together with samples of their supplies. This large company supports a line which traverses a distance of more than twenty-five hundred miles—from Donauwerth to the Black Sea—with auxiliary branches. They have 166 steamers, of collectively 148,116 indicated horse-power.

One of their larger steamers, the Orient, which is a fair sample of their vessels, is much like an American Hudson River steamer in general appearance. It is of rather light draught, (4 feet,) with high upper works and a number of state-rooms. This vessel is 250 feet long, of 27½ feet beam, and 9½ feet depth of hold. The number of berths is 178 and of state-rooms 11.

WIRE-ROPE TOWAGE.—One of the most interesting among the models shown by this company is that of a ferry-boat, the Waag. It is a vessel of 120 feet in length, 23 feet beam, and 6½ feet depth of hold. The draught is but 2½ feet. This vessel is propelled by "overhauling" a chain which lies along the bed of the river between Vienna and Pressburg. The same method is adopted on the Elbe and on other rivers of Europe for towage. The chain is laid on the river-bed, from end to end of the route. The steamer is provided with a winding-drum instead of paddle-wheels, and is thus fitted to haul in the chain at one end of the vessel and to pass it off at the other end.

The *Sächsische Dampfschiffs- und Maschinenbau- Anstalt*, of Dresden, also exhibited the machinery of a vessel of similar character, with steam-cylinders 12 inches diameter and 2 feet stroke.

Messrs. Sulzer Freres, of Winterthur, Switzerland, placed on exhibition machinery for wire-rope towage, constructed by them on the system of Baron De Mesnil and Herr Eyth, for a tow-boat to be employed on the Rhine by the Cologne Tow-Boat Company. The steam-engines had cylinders 14$\frac{3}{16}$ inches in diameter and 23⅝ inches stroke, well lagged, and fitted with steam-jacketed heads as well as sides. The expansion-gear consisted of link-motion and main and cut-off slide-valves, adjustable by hand to expand from $\frac{4}{3}$ to 10 times.

The steam is exhausted into tubular feed-water heaters and into a jet-condenser. The engines can be worked with or without condensation, as may be desired. The air-pump is 10 inches diameter. The engines are intended to make, as a maximum, 150 revolutions per minute. We found that steel had been used freely in their construction. The piston-rods, crank-shaft, and other important details were made of that metal. The clip-drum carrying the wire rope is 9 feet in diameter.

58. ROPE-TRACTION VS. PADDLE-WHEELS.—This method of propulsion, where practicable, is decidedly more economical of power than the ordinary methods, especially where, as in towing, the losses by slip and by oblique action of the paddle-floats become very serious. The total loss varies from an average of probably 25 or 30 per cent., in ordinary cases, to 55 per cent., and perhaps much more for tow-boats. It is somewhat remarkable that this method of propulsion, which is so common in Europe, should be so little practiced in the United States.

This appears the more remarkable when an analysis is made of the action of the paddle-wheel,* and the fact is thus shown that these losses by slip and oblique action, which are entirely avoided in chain-propulsion, are necessarily serious in the paddle-wheel. This analysis may be thus made:

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* Journal Franklin Institute, 1869.—Losses by oblique action in the paddle-wheel. R. H. Thurston.

In a marine steam-engine of good design and in good order, about 7 per cent. of the indicated horse-power may be expected to be consumed in the moving of the parts of the machinery itself, the remaining 93 per cent. being applied to the propelling-instrument.

Where the radial paddle-wheel is used, a considerable part of the work done by the wheel is expended uselessly in forcing the water downward, or in lifting it; and of that power which finally acts horizontally, a part is unavoidably lost in setting in motion the water upon which the wheel acts. Thus the power exerted by the *engines* is considerably greater than that exerted by the *ship* in resisting motion.

To ascertain the amount of these losses, when the vessel is at rest, as on the instant of starting the engines, the first of these losses, that from oblique action, is easily calculated, thus:

Measure the length of the immersed arc described by the center of pressure of the floats and the length of its chord. The ratio of the squares of these quantities will give the ratio of total power exerted to power expended horizontally by the wheel.

When the vessel moves ahead, the conditions of the problem are at once greatly changed.

The floats, then, instead of moving in a circle through the water, describe curtate cycloids.

They then move through the water obliquely, and with velocities varying every instant.

This forward movement of the vessel gives, to some extent, a "feathering" action to the floats, and the loss from oblique action becomes very greatly diminished.

The principal portion of the work is done in the lower portion of the path of the float, where there is less oblique action.

Noticing the positions assumed by the floats at different points, and the direction of their motion, it becomes evident, also, that the amount of "dip"* influences the amount of loss from oblique action very greatly when the vessel moves ahead, as well as in the previous case, and the most economical wheel will be that in which the sum of the losses from dip and slip are reduced to the greatest extent.

To ascertain the amount of loss of power in oblique action:

Let V = velocity of paddle-float at center of pressure.

v = velocity of vessel.

α = angle included between an arm, and horizontal line through the center.

β = any other angle.

$u = \frac{v}{V}$.

r = radius.

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* The "dip" is the depth of the lower edge of the paddle-float beneath the surface of the water.

The tangential velocity of the center of pressure of any float will be $(\mathrm{V} - v \sin \alpha) = \mathrm{V}\,(1 - u \sin \alpha)$, and the horizontal velocity through the water will be $(\mathrm{V} \sin \alpha - v) = \mathrm{V}\,(\sin \alpha - u)$.

The normal pressure on a unit of area of the float will be measured by the square of its velocity in the direction of that pressure, or $\mathrm{V}^2\,(1 - u \sin \alpha)^2$, and the total work done by the engine in turning the float throughout any arc will be—

$$r\mathrm{V}^2 \int_\alpha^\beta (1 - u \sin \alpha)^2\, d\alpha \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The horizontal component of the pressure on the float, which only is useful in propelling the ship, will be—

$$\mathrm{V}^2\,(1 - u \sin \alpha)^2 \sin \alpha$$

While the float is moving through the arc $r\,d\alpha$ in the time $d\,t = \frac{r\,d\alpha}{\mathrm{V}}$, this horizontal resistance will be met through a space $\mathrm{V}\,(\sin \alpha - u)\ dt = r\,d\alpha\ (\sin \alpha - u)$, and the power expended horizontally upon the water while the wheel moves through any elementary arc will, therefore, be expressed by $r\,\mathrm{V}^2\,(1 - u \sin \alpha)^2\ (\sin \alpha - u) \sin \alpha\, d\alpha$; and while moving through any arc, by—

$$r\,\mathrm{V}^2 \int_\alpha^\beta (1 - u \sin \alpha)^2\,(\sin \alpha - u) \sin \alpha\, d\alpha \ldots \quad (2)$$

But while this amount of work is expended upon the water, the wheel must, in consequence of the slip, do a greater amount of work in a proportion varying at each point with the slip, and the total horizontal work of the wheel will be obtained by multiplying the expression for the elementary arc by the factor $\frac{\mathrm{V}}{\mathrm{V}\,(1 - u \sin \alpha)}$.

The total amount of work done in this direction, then, while passing through the arc will be, including slip—

$$r\,\mathrm{V}^2 \int_\alpha^\beta (1 - u \sin \alpha)\,(\sin \alpha - u) \sin \alpha\, d\alpha \ldots \quad (3)$$

The ratio of (3) to (1) will be the ratio of gross horizontal work to the total work done on the wheel.

Integrating between limits, this ratio becomes—

$$\frac{(3)}{(1)} = \frac{\frac{u^2+1}{2}(\beta - \alpha) + 2u(\cos\beta - \cos\alpha) - \frac{u}{3}(\cos^3\beta - \cos^3\alpha) - \frac{u^2+1}{4}(\sin 2\beta - \sin 2\alpha)}{\frac{u^2+2}{2}(\beta - \alpha) + 2u(\cos\beta - \cos\alpha) - \frac{u^2}{4}(\sin 2\beta - \sin 2\alpha)}$$

In this equation, making α the angle of entrance of the mean center of pressure of the float,* and calling $\beta = 90°$, $\frac{v}{\mathrm{V}}$ being known, the loss of power in *any* wheel by oblique action may be obtained by subtracting the ratio resulting from our final equation from unity.

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* See paper by J. D. Van Buren, jr., Journal of the Franklin Institute, 1865.

The following are data assumed and results obtained as above:

First case.	Second case.	Third case.	Fourth case.
$\alpha=60^\circ=\frac{\pi}{3}=1.047$ $\beta=90^\circ=\frac{\pi}{2}=1.570$ $\frac{v}{V}=\frac{3}{4}$ Dip. $=\frac{3}{20}$ radius. Efficiency = .949. Loss by oblique action = .051.	$\alpha=42^\circ=\frac{7}{30}\pi$ $\beta=90^\circ=\frac{\pi}{2}$ $\frac{v}{V}=\frac{3}{4}$ Dip. = $\frac{1}{3}$ radius. Efficiency = .907. Loss = .093.	$\alpha=30^\circ=\frac{\pi}{6}$ $\beta=90^\circ=\frac{\pi}{2}$ $\frac{v}{V}=\frac{3}{4}$ Dip. = $\frac{1}{2}$ radius. Efficiency = .83. Loss = .17.	$\alpha=0^\circ=o.$ $\beta=90^\circ=\frac{\pi}{2}$ $\frac{v}{V}=\frac{3}{4}$ Dip. = to center. Efficiency = .70. Loss = .30.

The first case corresponds to that of light river-steamboats, the second to that of ocean-steamers, while the third is an exaggerated, though not remarkably rare, case. The fourth case is given simply in illustration of the use of the formula; it, of course, is unknown in practice.

Here the efficiency and loss are expressed, not in fractions of total indicated horse-power, but of the power applied to the wheel; and referred to indicated horse-power, those losses would be .047, .068, .158, and .28, respectively.

If it is required to find the loss of power by oblique action and slip combined, and thus to ascertain if the designer of the hull has fulfilled his guarantees, the net power expended in simply overcoming the resistance of the ship must be obtained. The amount of horizontal expenditure of power just obtained must, in this case, be reduced by multiplying by the ratio $\frac{V-v}{V}$, or it may be taken from (2.)

In the examples given above, the slip is assumed to be known, and in each case is taken at 25 per cent., and this net power usefully expended is found, after making this reduction, to be .714, .685, .631, and .52 of total indicated horse-power.

In the fourth case, the slip would actually be very much greater than is assumed above, and the efficiency would probably fall below 20 per centum of the indicated horse-power.

These results agree very closely with those deduced from experiment, and indicate very plainly the economy to be anticipated by the avoidance of these two serious sources of waste of power.

The screw is also subject to both sources of loss, but, working in a following current under the stern of the vessel, it enjoys a counterbalancing advantage which makes it superior to the paddle as an instrument of propulsion.

The objection to the adoption of the chain in general practice is the necessity of following closely the line along which it is laid. This difficulty is not, however, so great as it would at first seem. Boats thus propelled in some cases have turned around quite sharp bends, and readily avoid other craft by a slight change of course, and at the same time altering speed.

59. The engines exhibited by the DONAU GESELLSCHAFT were compound engines of exceptionally good design. One was a screw-engine with intermediate receiver; another was an oscillating paddle-engine, and the third large engine was an inclined engine. The trunk air-pump, the solid-bar Stephenson links, and other details gave good evidence that the designer was more than a mere copyist of the designs of others.

The solid-bar link seems gradually making its way into favor, and displacing the hitherto standard "open" or "strap" link. It has an important advantage in affording a means of taking up wear, and thus avoiding the shake and jar and the noise which follows from the slightest wear in the common link.

60. The STABILIMENTO TECHNICO TRIESTINO," an establishment located at Trieste, exhibited two sets of compound marine engines, which were very creditable indeed, and unexcelled by anything of the same class in the exhibition. These engines were of the " Napier style," well designed and well made, and had a sensible and serviceable appearance, which was quite in contrast with that of some competing specimens of marine work. The finish was plain, but quite as good as should be asked, and the amount of " bright-work" about them was reduced to the least amount consistent with good appearance. The builders evidently understood that much highly-finished work on a marine engine is out of place.

The 150 N. H. P. engines are provided with a centrifugal circulating-pump, driven by an independent engine. This arrangement is in some respects a very excellent one, and it is apparently becoming standard practice. With a plain, simple engine and an effective form of circulating-pump, no objection exists to its adoption.

The large pair of engines had steam-jacketed cylinders, 31 and 60 inches in diameter, and a stroke of piston of 3 feet. The method of securing the inner barrels of the cylinder to the outer casing so as to be at once steam-tight and rigid, in spite of changes of dimensions due to changes of temperature, was stated to be similar to that now generally practiced in Great Britain. It is so excellent and in every way satisfactory that it should be more generally known in the United States. At the lower end, the linings are secured rigidly to the main cylinder-casting by bolted flanges. At the upper ends, the barrel fits snugly, but without jamming, and a stuffing-box is made between it and the casing. This stuffing-box is filled with a wire-rope packing, sometimes of galvanized wire, and with white lead. It is driven in snugly and confined by an annular ring bolted firmly down upon it.

The " box-framing" forms also the hot-well. The surface-condenser is cleared by a single-acting air-pump of 26 inches diameter and 1½ feet stroke. The feed-pumps and the bilge-pumps are driven from the cross-head of the air-pump.

61. Messrs. JOHN PENN & SON, of Greenwich, Great Britain, exhibited a beautifully-made and exquisitely-finished model of one of their marine trunk-engines of large size, such as was fitted up in the British iron-clad Minotaur and vessels of similar character. This form of engine has been built by this firm for many years, and, as constructed by them, has proved itself a very effective machine. In the hands of less experienced and less skillful builders, however, it has not succeeded, and it is generally regarded by engineers as an undesirable form of marine engine. Messrs. Penn & Son are themselves now building compound engines.

The Minotaur was one of the earlier of the British iron-clads. The great length and consequent difficulty of manoeuvring, the defect of speed, and the weakness of armor of these vessels have led to the substitution of far more effective designs in later constructions. The Minotaur is a four-masted screw iron-clad, 400 feet long, of 59 feet beam and 26½ feet draught of water. Her speed at sea is about 12½ knots, and her engines develop, as a maximum, nearly 6,000 indicated horse-power. Her heaviest armor-plates are but 6 inches in thickness. Her extreme length and her unbalanced rudder make it difficult to turn rapidly. With *eighteen men at the steering-wheel* and sixty others on the tackle, the ship, on one occasion, was 7½ minutes in turning completely around.

These long iron-clads were succeeded by the shorter vessels designed by Mr. E. J. Reed, of which the first, the Bellerophon, was of 4,246 tons burden, 300 feet long by 56 feet beam, and 24½ feet draught, of the 14-knot speed with 4,600 horse-power; and, having the "balanced rudder" used many years earlier in the United States by Robert L. Stevens,* it can turn in four minutes with eight men at the wheel. The cost of construction was some $600,000 less than that of the Minotaur.

62. The "SOCIÉTÉ JOHN COCKERILL," of Seraing, Belgium, exhibited a well-made pair of large oscillating engines, with feathering-paddle wheels, such as are very common in Great Britain and in the continental harbors and rivers. They presented no essential peculiarity of design and the remarks just made with reference to the trunk-engine will apply with almost equal force here.

63. THE FEATHERING-PADDLE is often used in Europe to the exclusion of the common or "radial" wheel, over which it possesses some decided advantages. As usually made, the diameter of the feathering-wheel is one-half that of a radial wheel acting similarly upon the water. In other words, the floats traverse the water as if they were attached to a radial wheel of double diameter. This reduction of size permits the use of a smaller engine, making a greater number of revolutions, and thus cheapens its cost, permits a high speed of piston, and produces

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*It is still in use on the Hoboken ferry-boats, and has now been largely introduced in naval vessels.

some economy. The small paddle-boxes present a comparatively small surface to the wind, and, by thus reducing head-resistance, give increased speed.

The disadvantages of this wheel are its complication and the expense of constructing it. In the United States, where the navigable rivers are usually obstructed by ice during some months in each year, it is impossible to adopt it with advantage. In Europe, where this rarely occurs, the feathering-paddle is almost universally used.

64. The high rate of speed required for economical expansive working is obtained in the United States by adopting the typical "American" overhead-beam engine, of which the long stroke of piston, the ease of working, and the readiness with which it accommodates itself, without difficulty, to changes in the shape of our flexible vessels, render it probably the best possible type to couple with our great radial wheels. It is only excelled in economy by the best compound-engines.

Some manufacturing firms, among them the principal Montreal engine-builders, are "compounding" this engine with satisfactory results.

This engine can readily be adapted to the feathering-wheel, and its use on the rivers and harbors of the South and in boats intended only for summer travel in the North would prove, if properly designed, satisfactorily economical.

65. Among the most interesting exhibits of marine machinery were the compound-engines of the Swedish twin-screw gunboats, exhibited by the MOTALA WORKS. These were horizontal compound-engines, with an intermediate receiver, with cranks set at right angles. The steam-cylinders were 10 and 20 inches in diameter, and the stroke of pistons 17$\frac{1}{2}$ inches. The air-pumps were 7$\frac{3}{8}$ inches in diameter and 8$\frac{3}{4}$ inches stroke. The cylinders were not steam-jacketed. The valves were the ordinary slide, driven by a link-motion. The engines were fitted with jet-condensers.

The steam-boilers supplying these engines were stated to be tubular boilers of 950 square feet of heating-surface, and 26$\frac{1}{2}$ feet of grate-surface.

The engines built from the same designs for the gunboat Ulf were said to have developed 160 indicated horse-power, with a consumption of less than 2$\frac{1}{2}$ pounds of coal per horse-power per hour.

66. The Motala Works also exhibited a small passenger-steamer on the river. This little craft, the Motala, was 56$\frac{1}{2}$ feet long, 11$\frac{2}{3}$ feet beam, and drew, loaded, 4$\frac{1}{4}$ feet of water. It was driven by a plain non-condensing engine of 8 horse-power. The screw was 3$\frac{1}{6}$ feet diameter, 6$\frac{3}{4}$ feet pitch, and the boiler, of locomotive type, contained 120 square feet of heating-surface, and 3$\frac{3}{4}$ square feet of grate-surface.

CHAPTER III.

LOCOMOTIVE-ENGINES.

NUMBER EXHIBITED, DIMENSIONS; TABLE; AMERICAN LOCOMOTIVES; BRITISH TANK-ENGINES; LOCOMOTIVES OF MM. HENRI SCHNEIDER & CO., MM. CLAPAREDE, THE COMPAGNIE DE FIVES-LILLE, THE SOCIÉTÉ JOHN COCKERILL, THE SOCIÉTÉ ANONYME DE COUILLET; THE GUINOTTE VALVE-GEAR, ITS DESIGN, CONSTRUCTION, APPLICATION TO REVERSING-ENGINES; PECULIAR APPLICATIONS; USE ON HOISTING-ENGINES; AUTOMATIC ADJUSTMENT; CAREL'S LOCOMOTIVE; RUSSIAN, ITALIAN, GERMAN, AND AUSTRIAN LOCOMOTIVES; THE STAATS EISENBAHN-GESELLSCHAFT; CHARACTER OF EUROPEAN WORK; BELPAIRE'S FIRE-BOX; STEAM-PRESSURES; RIVETING AND CALKING; MATERIAL—STEEL VS. IRON; KRUPP'S STEEL WHEELS; IRON WHEELS HISTORICAL; THE INTRODUCTION OF STEEL.

67. NUMBER AND DIMENSIONS.—More than forty locomotive-engines were exhibited at Vienna, all, with a single exception, having outside cylinders; the diameter of cylinders, varying from 8½ to 21½ inches, was usually 16½ or 17 inches. The driving-wheels ranged from 2½ feet diameter on a little English contractors' locomotive, to 6½ feet on two of the German engines. The weights of engines, in working order, ranged from 6½ to 70 tons.

68. The accompanying table, published in London Engineering, of date of June 6, 1873, contains the leading dimensions of nearly all; and, so far as the writer has been able to check it, it is very accurate:

69. AMERICAN LOCOMOTIVES.—It will be noticed that no American locomotive was exhibited.

Our builders seem to have assumed that no advantage would be gained by exhibiting at Vienna. This was probably an error. The American locomotive, which was formerly looked upon with little favor by European constructors, is now well known, and its advantages are well recognized. The fact that continental builders, and to a less extent the British, are copying it, both in general plan and in details, is the best evidence of the truth of this statement. One American firm has recently received a large European order, which, it is not unlikely, was prompted partly, if not wholly, by the exhibition of American locomotives in 1867, in Paris. Even more satisfactory returns might have been anticipated from similar enterprise in 1873. The reputation of American mechanics and engineers in Europe has steadily and rapidly increased since 1867, and a strongly favorable impression now exists, which, if properly taken advantage of by our people, will be found of great assistance in securing foreign orders and in the introduction into Europe of good American inventions.

That the American locomotive is looked upon with great favor by European engineers is indicated not only by the gradual adoption of that design in construction, but, in the case of Russia, particularly, by extensive purchases from firms in the United States. The Baldwin Locomotive Works, of Philadelphia, have sold a considerable number to the Russian lines of railroad, and the Grant Locomotive Works have concluded negotiations for the sale of fifty engines in a single contract. It is stated that these engines will be built for burning anthracite coal, of which a considerable deposit exists in that country.

The work done in Europe by our countrymen, Whistler, Harrison, Winans, and others, is still exerting an influence, to some extent traditional in origin but still proverbial, in favor of the work of American mechanics. The reputation of this nation abroad for ingenuity, tact, and power of adaptation to circumstances is largely due to them.

70. BRITISH TANK-ENGINES.—The British section contained two tank-engines, of good workmanship, and apparently of excellent material. The design is in each case neat, and the engines seem well fitted for doing good work. One, by FOX, WALKER & CO., of Bristol, was built for $3\frac{1}{2}$ feet width of gauge, and was fitted with the Le Chatelier counter-pressure brake and a rude spark-arrester. It had outside cylinders, of 10 inches diameter and 18 inches stroke; driving-wheel, 3 feet diameter, with axles 6 feet from center to center, a pair of leading-wheels $2\frac{1}{4}$ feet diameter, fitted up with the radial axle-boxes applied by Adams. The boiler contained 96 tubes $1\frac{3}{4}$ inches diameter and $8\frac{1}{6}$ feet long; its total heating-surface was 406 square feet and its grate-surface $7\frac{1}{2}$ feet. The engine, in working order, weighed 18 tons, of which 66 per cent. was carried on the driving-wheels. Without fuel and water, the weight was 15 tons. It was fitted with "ring-tanks," and the coal was carried on the foot-board.

The other engine, by HUGHES & CO., of Loughborough, had cylinders $8\frac{1}{2}$ inches diameter by $1\frac{1}{4}$ feet stroke; driving-wheels, $2\frac{1}{2}$ feet diameter and $4\frac{1}{2}$ feet from center to center of axles; heating-surface, 235 square feet; grate-surface, 5 feet; weight, 10 tons in working order, 8 tons empty; tank extending over the top of the boiler.

71. FRENCH LOCOMOTIVES.—France was represented in this class by three engines. One built by MM. SCHNEIDER & CIE, of Creuzot, for the Chemin de Fer du Midi, was a powerful outside-cylinder freight-engine, with eight coupled wheels. It was well designed, of excellent proportions, and the most beautifully finished locomotive in the Exhibition. It had a large area of grate, 20 square feet, (2.4 square meters,) and 208 square meters, (nearly 2,500 square feet,) of heating-surface. The cylinders were $21\frac{1}{4}$ inches (0.54 meter) diameter, with a stroke of piston of 2 feet, (0.61 meter.) Its weight was nearly 54 tons in working order. By giving a certain amonut of play (0.20 meter) to the axles, it had been made capable, as was supposed, of running smoothly around curves of 1,000 feet radius. The connecting-rods were made with lateral

joints to avoid strain. It was a fine piece of work, but lacked the flexibility and easiness which are best seen in the American type of locomotive. As a specimen of good work, it was unsurpassed. The running-gear was all of steel. Its tender was not exhibited, but was said to have a weight, loaded, of about 18 tons.

A pump and injector were attached, the former on the right, the latter on the left hand side of the engine. The Le Chatelier counter-pressure brake is used, and a screw-brake is also attached.

The wheels were 47¼ inches in diameter, and their axles were spaced about 4¼ feet apart, giving a wheel-base of 12⅝ feet. The boiler was 5 feet diameter of shell and 22½ feet long; the tubes were 2 inches in diameter, 16 feet long, and one-tenth of an inch thick. Steam-pressure was to be carried at about 125 pounds per square inch.

72. The other locomotives in the French section were exhibited by MM. CLAPAREDE and by LA COMPAGNIE DE FIVES-LILLE. That of the first-named firm was a plain machine of ordinary finish, and seemed a serviceable engine. It had six wheels, all coupled. The cylinders were 19 inches (0.48 meter) diameter and 26 inches (0.65 meter) stroke. It was designed by M. Forquenot, the engineer of the Paris and Orleans Railroad Company. The diameter of wheels was 4½ feet; length of wheel-base, 11¼ feet; and its width from frame to frame was 4 feet. The boiler had a shell 4½ feet in diameter, of one-half-inch iron, with 2-inch tubes 14½ feet long. The heating-surface was about 1,650 square feet; grate-surface, 16 square feet. The engine weighed 35 tons empty, or 38 tons on the line. A stay-plate at the middle of the boiler supports the tubes; the piston-rods pass through both heads. Many of the details of this engine seemed badly proportioned and awkwardly arranged.

73. The engine of the second exhibitor was a small tank-engine with six wheels, all coupled and fitted to a track of one meter (3.28 feet) breadth of gauge. The weight of the engine was but 14 tons, and its cylinders had a diameter of 10 inches (0.25 meter) and a stroke of piston of 14½ inches (0.36 meter.) It was claimed to be capable of drawing 220 tons 20 kilometers (twelve and one-half miles) per hour on a level track. The distance between forward and after axles was 1.72 meters, (5 feet 8 inches,) and, as is usual in American practice, the middle pair of wheels were fitted with tires without flanges. It might be expected, therefore, to move freely on a sharp curve.

A Friedmann injector, a form which seems a favorite in Europe,* and a pump were attached to the boiler.

74. THE BELGIAN LOCOMOTIVES exhibit fairly the excellent position which their manufacturers have assumed in Europe. They are only second to those of Great Britain, although both France and Switzerland are rivaling them very closely.

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* It has now been introduced into the United States by Messrs. Nathan & Dreyfus. Giffard's injector, and its modifications, seem to be more exclusively used in Europe than in the United States.

Fig. 25

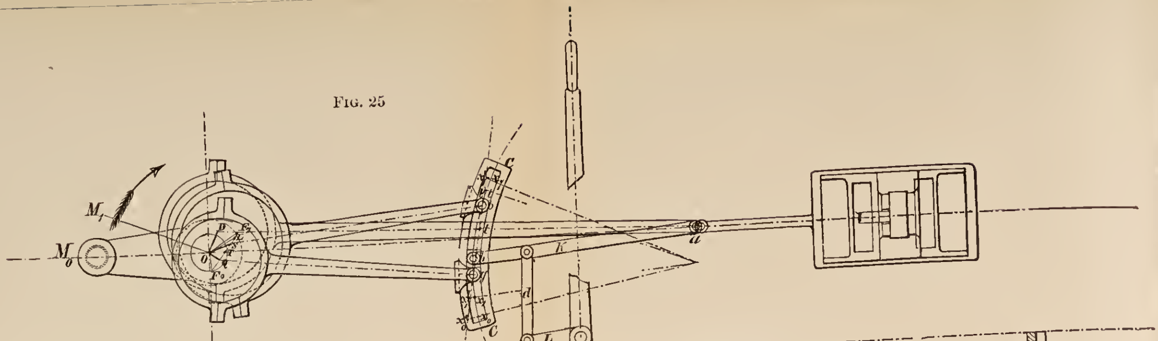


Fig. 26

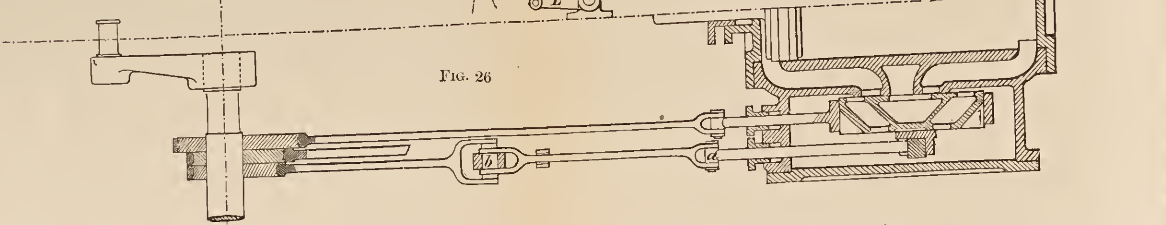


Fig. 27

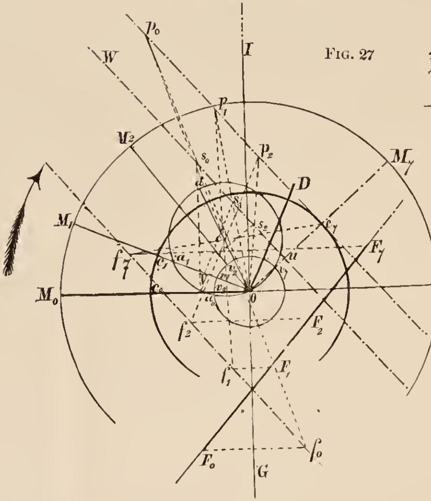
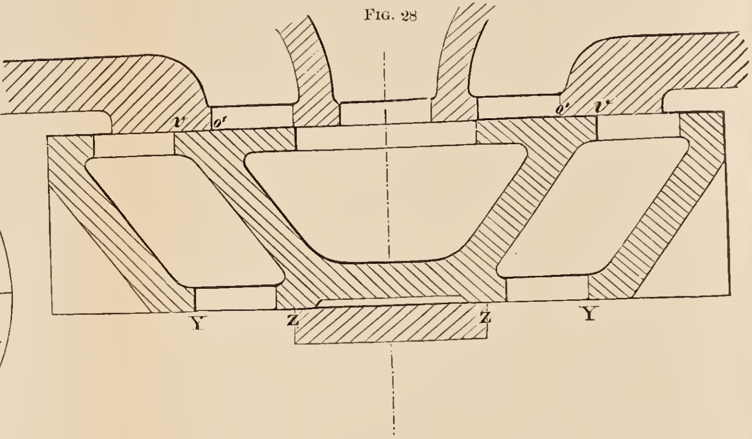


Fig. 28



The Guinotte valve-gear.

The SOCIÉTÉ, JOHN COCKERILL, of Seraing, exhibited two machines, of good design and plain finish, which seemed capable of making excellent performance. The larger one was intended for an Italian road which had already purchased nearly fifty locomotives from the same builders. This engine carries injectors under the foot-plate. The piston-rods are carried through both cylinder-heads, a plan which has manifest objections and which has been adopted to overcome difficulties which are perhaps imaginary rather than real. The smaller engine is a plain contractors' tank-engine, which requires no special notice.

75. The GRAND CENTRAL RAILWAY, of Belgium, exhibited a passenger locomotive built by the Société Anonymé de Couillet, as one of a lot of twenty-five built on one order. They are intended to draw trains of twenty or more carriages, at a speed of over thirty-five miles per hour, over a road having gradients of 20 to 50 feet per mile. The engine has six wheels, four of them coupled. The cylinders are 0.44 meter, (17½ inches,) with a stroke of piston of 0.60 meter, (24 inches.) The weight of the engine ready for work is 33 tons. This engine is most creditable in general design, in material, and in workmanship. The steam-cylinders are placed between the leading and middle wheels, the trailing-wheels being the drivers. Immensely long guide-bars, a Walschaert main-valve gear, with the Guinotte expansion-gear, are the peculiarities of this engine. The main valve is always kept at full gear while running, the point of cut-off being determined by the expansion-gear. In reversing, the main-valve gear is used, and the point of cut-off remains unaltered by the change of direction.

76. THE GUINOTTE VALVE-GEAR.—A model of the Guinotte valve-gear was exhibited, which was intended to facilitate the study by engineers of the system of variable cut-off invented by that gentleman. Its construction is very simple, but it requires some study to be well understood. This system has been successfully applied to hoisting-engines about three years. The Exhibition contains two characteristic examples of this gear: one on a locomotive of the Belgian Grand Central Railroad type, which is exhibited by the Société Anonymé de Marcinelle et Couillet, and one on a hoisting-engine of 250 horse-power, to be sent to the Société de Kladno, (Austria,) exhibited by Messrs. Quillacq & Co., of Anzin, (France, département du nord,) and placed in Group 1 of the French section.

This system of valve-gearing consists of two superposed slide-valves; the second, or cut-off valve, being single and rigidly fixed to its valve-rod.

77. Figs. 25 and 26 show its general construction for a non-reversible engine. The crank is supposed to be at its dead center, M_0, and the direction of rotation is indicated by the arrow. The steam-valve is worked by an ordinary eccentric, of which the center is at D. The cut-off valve is worked by means of the valve-rod jointed to the rod of the cut-off valve at *a*, and to a connecting-rod, which can be moved in the link C C at *b*.

This link is worked:

1. At g by an eccentric keyed to the main shaft, its radius being O Q, and its center being at Q when the crank is at M_0.

2. At b by an eccentric, also keyed to the main shaft, its radius being O S, and its center being at S when the crank is at M_0.

The link is hung by means of the rod d jointed to the valve-rod K and to the lever L, which varies the cut-off.

If the link is at x_0, there will be no steam admitted; if it is placed at x_1, steam will be admitted while the crank is revolving through M_0 M_1, and so on. The admission can be varied to any extent from total suppression to a point at which steam is admitted during the whole stroke, the variation being produced by moving the link-block* in the link.

Let us suppose the eccentric of the steam-valve to be represented by its radius OD, (Fig. 27,) the crank being supposed to be at M_0. Draw Od symmetrically with OD with reference to the line IG, which is perpendicular to the line joining the two dead centers. On Od as a diameter, draw the circle a_0 a_1 a_2 . . . . , having c as the center.

With O as a center, draw the circle v_0 v_1 v_2 . . . . . . , its radius being taken equal to the inside lap of the edges of the steam slide-valve, the lap being measured by o^1 v^1 in Fig. 28.

Draw the radius of the crank OM_7, passing through the point of intersection v_7 of the two above-mentioned circles. The radius OM_7 indicates the position of the crank when the steam-port of the cylinder is closed, *i. e.*, that position in which the edges O^1 and v^1 (Fig. 28) coincide.

With O as a center draw the circle c_0 c_1 c_2 . . . . . . , having a radius equal to the distance between the edge y of the steam-valve and the edge z of the cut-off valve, when the axes of symmetry coincide as in Fig. 28.

Through the middle of Oc_7 and perpendicular to it, draw the line uW upon the radius OM_7; through the point c_7 draw p_0 c_7 parallel to uW. Draw f_0 f_7 parallel to the line p_0 c_7 and on the other side of, and equally distant from, the center c. Finally draw the line F_0 F_7 symmetrical to f_0 f_7, with reference to the line IG.

The first part of the problem will be solved when we have found the line F_0 F_7. It can be clearly shown that if the cut-off valve, instead of being worked by an eccentric of a fixed throw, be worked by an eccentric of a variable throw, and whose center could be displaced at will along the straight line joining F_0 and F_7 (so as to make the lines joining the different points of F_0 F_7 with the center O express the different pos-

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* Those who desire to study the subject thoroughly may consult the following special memoirs, in which the subject has been fully treated:

Étude générale sur la détente variable. Liége, 1872.

Variable expansion gear, designed by M. Lucien Guinotte, director of the Mariemont and Bascoup collieries, Belgium.

Engineering, September 29, 1871.

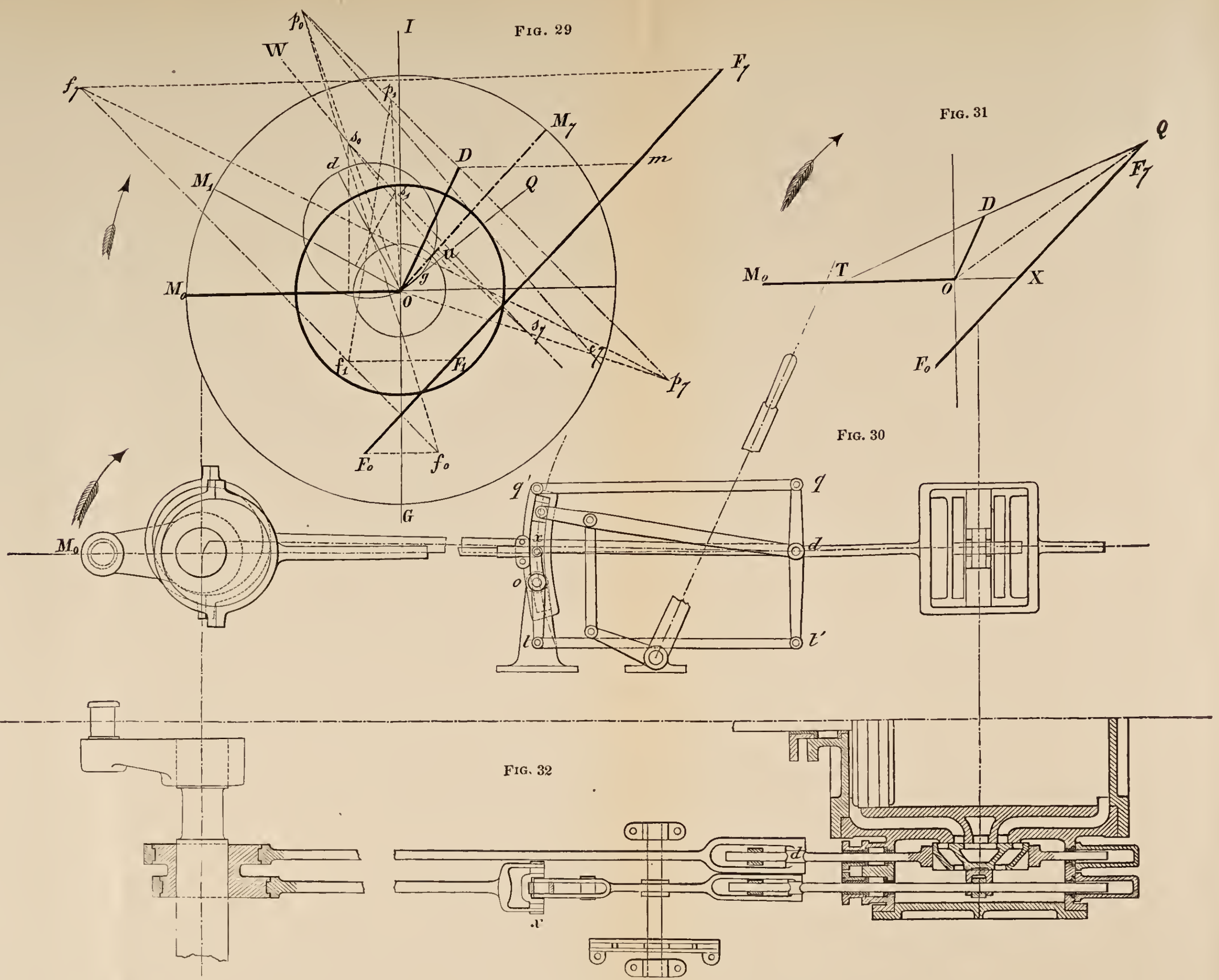
Les Houilleries en 1872, par Amédée Burat. Paris, 1872.

Fig. 29

Fig. 31

Fig. 30

Fig. 32



The Guinotte valve-gear.

sible lengths and positions of the radius of the eccentric, the crank being supposed to remain at OM_0,) then the period of the admission of steam into the cylinder would be varied at will, from no admission up to full admission.

To indicate the method of finding the position of the center of the eccentric for every period of admission, as, for example, that corresponding to the movement of the crank from M_0 to M_1:

On the radius OM_1, and through the middle point V of Oc_1, erect a perpendicular Vs_1. This will cut uW in s_1. Draw the straight line Os_1 and prolong it until it intersects the line $p_0\ c_7$ in p_1. Join c and p_1 by a straight line, and continue it until it cuts $f_0\ f_7$ in f_1. Through f_1 draw a perpendicular to IG and prolong it until it cuts the line $F_0\ F_7$ in F_1.

F_1 is the point sought, being the position of the center of the eccentric for the admission $M_0\ M_1$, when the crank is at M_0.

Proceeding in the same manner with the radii OM_0 and OM_7, the extreme points F_0 and F_7 of the throw, which the center of the eccentric should be capable of, to produce a variation in the period of admission, within the limits mentioned before, are found.

In the same manner, by operating upon the radius OM_2, the position F_2, which the center of the cut-off's eccentric should occupy for the period of admission corresponding to the travel $M^\circ\ M_2$, of the crank, is obtained.

Theoretically, in Fig. 27, the port of the cut-off valve will re-open, for all periods of admission when the radius of the crank arrives at $O\,M_{17}$, the moment when the steam-port is closed by the steam-valve. This arrangement would evidently not be efficient, as the slightest wear would destroy the proper distribution of steam. Fig. 27 must be modified to make the distribution a practicable one, as shown in Fig. 29. This differs from the first in the following particulars:

1st. Instead of being constructed upon the radius $O\,M_{17}$, the drawing is made by taking the radius $O\,Q$. When the crank assumes the position of this radius the steam-valve covers the port by an amount equal to $r\ g$.

2d. The line UW, or $o_\circ$ U, is replaced by the line $o_\circ\ o_7$; the line $p_0\ c_7$ is replaced by $p_\circ\ p_7$.

By inspecting Figs. 27 and 29 we may infer immediately what effect this change will have upon the line $f_\circ\ f_7$, and upon the line $F_\circ\ F_7$.

78. It now remains to realize in practice the principle enunciated above, as found and demonstrated. In other words, we must obtain the same result as if the center of the cut-off eccentric could be moved at will along the line $F_\circ\ F_7$, determined in the manner just shown.

Returning to Fig. 25, in which the line $F_\circ\ F_7$ has the same significance as in Figs. 27 and 29, the crank is supposed to be at $M_\circ$, and the two eccentrics $O\,Q$ and $O\,S$ drive the points q and s of the link. If the eccentric rods are long enough, and if the curvature of the link is not too sharp, (this can always be easily realized,) then, without an appreciable error—

1st. We can substitute for the geometrical motion of the curved line $x_o\,x_7$, that of the straight line $q\,s$, passing through the joints of the eccentric rods.

2d. We can say that, when the system is set in motion, the points q and s will move in the same manner as the projections of the eccentrics Q and S upon the axis OM_o.

It is, therefore, easy to show that any point t, of the line $q\,s$, will move with the projection, upon the axis OM_o, of a point T, which is the extremity of an imaginary eccentric OT, so determined that

$$\frac{Q\,T}{T\,S} = \frac{q\,t}{t\,s}$$

Similarly the other points, x_0, l, x_7 ...... of the link will move, as if they were worked by eccentrics O F_0, O L, O F_7, these points being such that

$$\frac{F_0\,S}{F_0\,Q} = \frac{x'_0\,s}{x'_0\,q}$$

$$\frac{L\,S}{L\,Q} = \frac{l'\,s}{l'\,q}$$

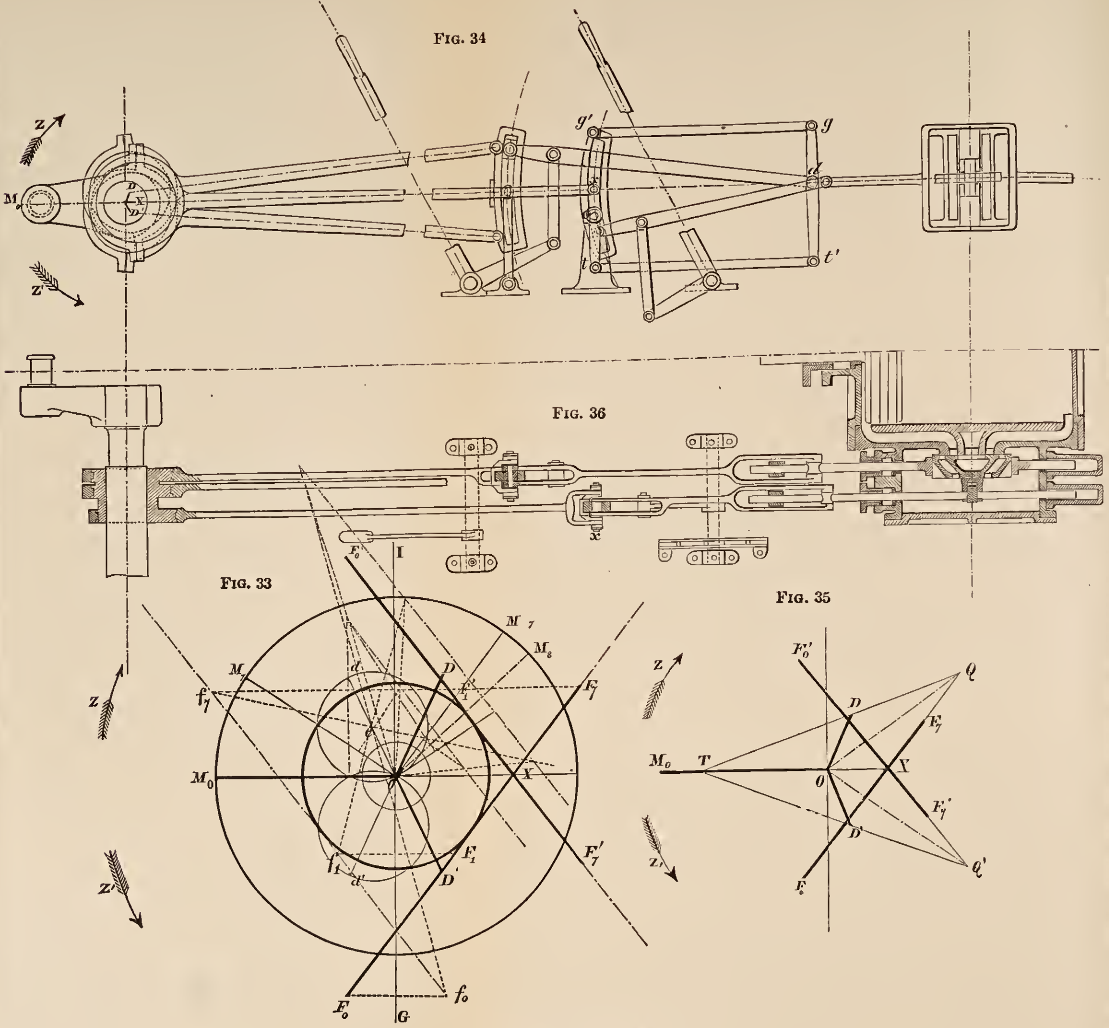
$$\frac{F_{17}\,S}{F_{17}\,Q} = \frac{x'_7\,s}{x'_7\,q}$$

It follows that by moving the connecting-rod to different points along the link, the cut-off valve will receive different and varying motions, as if the center of the cut-off eccentric had been moved along the line $F_0\,F_7$. The cut-off will therefore be variable within the widest limits.

The object of the construction shown in Figs. 25 and 26 was to assist in explaining the system and in resolving the principles which unite in the solution. This arrangement is not usually employed. That shown in Figs. 30 and 31 is at once more simple, more elegant, more exact, and easier in its application, and it requires but a single eccentric. In describing it we will, at the same time, employ Fig. 31, which gives the proportions of all parts.

O D always represents the radius and the throw of the eccentric of the steam-valve, the crank being at M_0. The line $F_0\,F_7$ or the line connecting the centers of the cut-off eccentrics having the same significance as in the preceding figures, intersects the line of dead points M_0 O in X. An eccentric O X, opposite to the crank, moves the point x of the cut-off link, and simultaneously the extremity of a lever, $x\,o\,t$, vibrating about a fixed o. The point t receives the same motion as though it were attached to an imaginary eccentric O T, such that $\frac{O\,T}{O\,X} = \frac{o\,t.}{o\,x.}$ The motion of t is communicated to the joint t', of the lever $t'\,d\,q$, by means of the rod $t\,t'$. This lever is jointed to the valve-stem of the steam-valve at d—a point which partakes of the motion of the steam-valve eccentric O D.

Join T and D and prolong the line to Q. The points t' and d, of the



The Guinotte valve-gear.

lever $t' d q$, being moved like the projections of the eccentrics T and D, a third point, q, so situated that $\frac{q d}{q t} = \frac{\text{Q D}}{\text{Q T}}$, will move like the projection of an eccentric O Q; that is, it will be moved as though it were actuated by an eccentric O Q. The same end will be attained by communicating this motion to the point q of the link by means of the rod $q q'$. The combination of levers $t o x$ and $t' d q$ then allows the eccentric O Q to be dispensed with, and the obliquity of the eccentric-rods to be avoided.

79. This construction being understood, we may consider the application of the system to engines having a reversing motion.

The crank being at M_0, (Fig. 33,) the center of the steam-valve eccentric is at D when the engine moves in the direction of the arrow Z, and at D′ when the engine moves in the direction of the arrow Z′.

Let us consider the two directions of motion separately—first the eccentric D, and then the eccentric D′, as for an engine having but one direction of motion. We will then find the line of F_0 F_1 . . . . . . F_{17}, to be the line of centers of the cut-off eccentrics for the direction of motion Z, and the line F'_0 F'_1 . . . . . . F'_{17} for the direction Z′. These two lines will intersect at X, on the line of dead-centers M_0 O, being the prolongation of the radius of the crank. One of the points of the link can then be marked by an eccentric OX, and the motion of this point will follow equally well the direction Z and the direction Z′.

The problem is then to obtain another point of the cut-off link, such that no additional operation is required in reversal of the motion. This is done by adapting the construction seen in Figs. 30 and 32, which is given for reversible engines in Figs. 34 and 36. The design shown in Fig. 35 represents the proportions of the parts, their number not having been increased.

When motion takes place in the direction Z, the point t', of the lever $t' d q$, is moved as though it were worked by an eccentric OD; the point d is moved as though it were worked by an eccentric OD. Therefore the point q, and the point g' of the link, move as though actuated by an eccentric OD.

Suppose the motion reversed by the ordinary means, and taking place in the direction Z′. The point t' will have the same motion as before, but the point d will move as though it were worked by an eccentric OD′, instead of OD, and hence the point q, and the point g' of the link, will be worked by an eccentric OQ′.

The line joining the two points of application of the driving force at x and g' will then represent the line XQ for the motion Z, and the line XQ′ for the motion Z′.

This also may be stated thus:

In changing the position of the lever, the position of the point g' of the link will change of itself, and the link will represent the line F_0 F_7, accordingly as the reversing lever is thrown to one side or to the other. Otherwise stated, the reversal of the motion does not merely reverse the position of the steam-valve, but it also changes the cut-off valve, so that this is also set properly for the opposite direction of motion of the engine. The period of admission will not be changed. This result is obtained without the use of additional levers, and the engineer has nothing more to do than in the case of simple reversing engines without cut-off. The lever for the variable cut-off should be worked for no other purpose than to change the period of admission.

80. The preceding statement is sufficient to show to how many different combinations this system may be applied, and to show how easy it is to apply it in each particular case. Space will not permit entering into details, and we will only consider two or three cases, showing some remarkable peculiarities. First, however, the attention should be drawn to a point of great importance in all reversing engines.

One of the principal conditions to be realized in these engines is, to avoid increasing the difficulty which the engineer meets with in working his reversing-lever. This condition is evidently realized. Not only does the cut-off valve have an extremely small area, (much smaller than that of the cut-off valve of any other system,) but the connecting-link is in such a position that the motion which the engineer gives to the valves in reversing is identically the same for both steam and cut-off valve.

It follows, therefore, that the resistance, which he must overcome, is the same as though he only had to move the steam-valve, for the cut-off valve moves simultaneously, and, therefore, does not produce extra friction. The position of the connecting-link is that which corresponds to the point m of the line F_0 F_7 on the slot, in Fig. 29. This point m is formed by drawing a line parallel to the line of dead-centers through D, until it intersects F_0 F_7 in m. The model exhibited this fact. It may also be easily demonstrated theoretically. This position, which may be called the *working position*, is constant on the index-sector of the cut-off lever. It generally corresponds to the point of full admission.

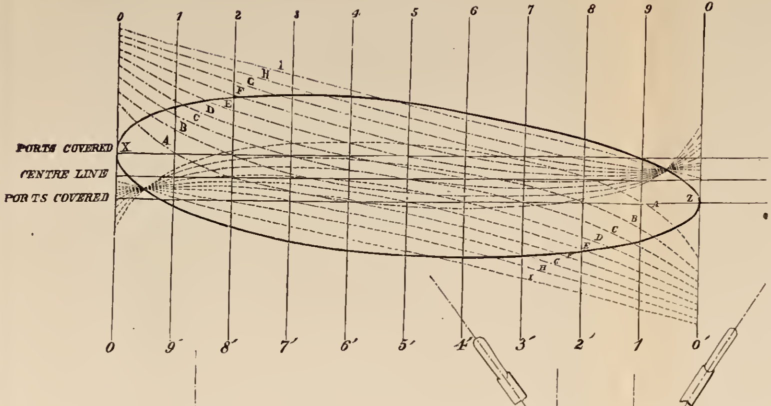
The motion of the steam-valve on the locomotive exhibited by the Société de Couillet is of the Walschaertz system, which has but one eccentric, and the Guinotte system of cut-off is applied without adding a second eccentric. That usually employed is replaced by a lever, worked by the cross-head, as Walschaertz moves his steam-valve.

81. The hoisting-engine exhibited by Messrs. Quillacq & Co., shows another arrangement. It is shown in Fig. 37, and Fig. 38 shows the result obtained for different periods of admission.

The full-lined curve shows the positions of the steam-valve for different positions of the piston. The distance between the curve and lines of the points of re-opening, x and z, indicates the opening of the steam-port for each point in the stroke of the piston.

The dotted lines indicate the closing of the steam-ports by the cut-off valve, according to the position occupied by the connecting-rod in the

Fig. 38



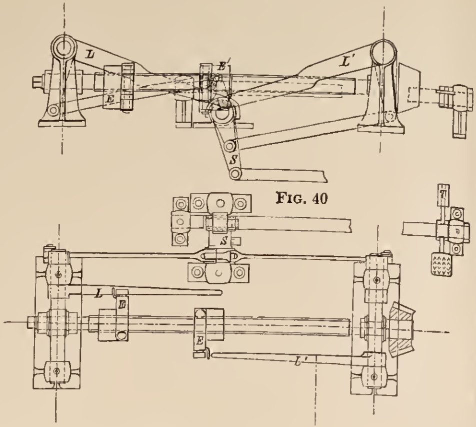


Fig. 40

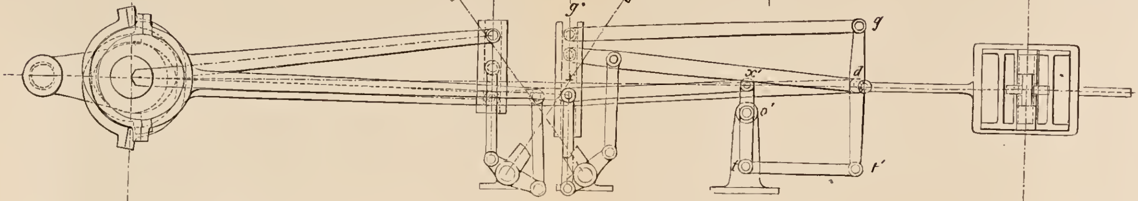


Fig. 37

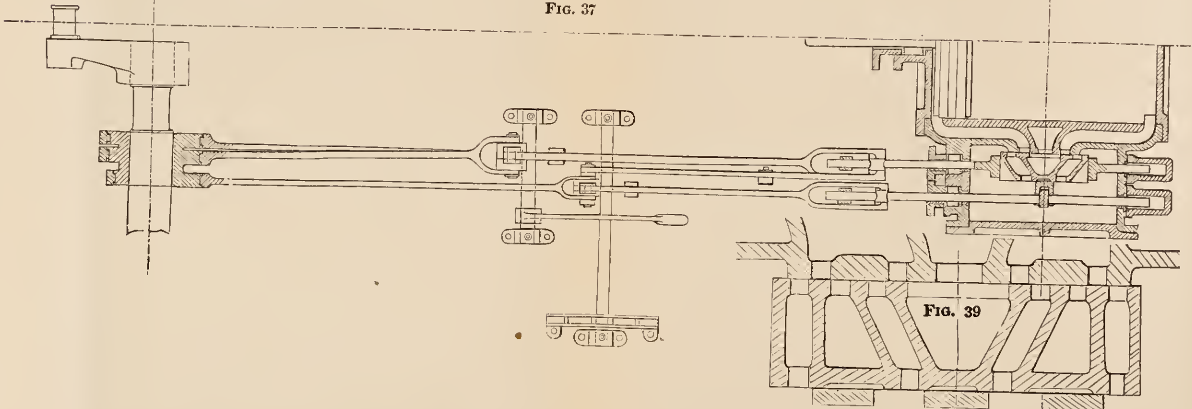


Fig. 39

The Guinotte valve-gear.

link. The lines, marked with the same letter, correspond to the front and the back ends of the cylinder, the position of the connecting-link being the same.

The reverse motion gives a construction which does not differ materially from the preceding.

Finally, in Fig. 39 is shown the arrangement adopted in several cases already for the slide-valves of powerful hoisting-engines. As shown, the steam-ports are divided into two parts, and the expansion-valve is formed of three pieces, bound firmly together and constituting but a single piece. This arrangement increases the bearing surfaces of the valves slightly, but it also decreases the length of travel; therefore, the reversing-lever moves easily. Repeated trials indicate that a man of ordinary strength can easily handle a pair of engines of 47½ inches diameter of cylinder, provided with the expansion-gearing, where the valves are arranged as shown in Fig. 39.

Another advantage of this system of expansion-gear, peculiar to hoisting-engines, is that it affords a complete solution of the problem of the regulation of such engines.

82. The expansion-gear may be made continually variable automatically, according to any law which may serve to establish a constant equilibrium between the driving force and the resistance. All that is necessary for this purpose is that the connecting-link of the expansion-gear be moved by the engine itself, instead of being worked by the engine-driver. The model exhibited at Vienna was made to illustrate both cases. By connecting the forward with the backing gear thus arranged, the model is made to illustrate the case of a hoisting-engine, the power of which varies at every instant, according to a law determined by the curvature of the lever on either side the endless screw driven by the main shaft. A mere inspection of the model, as of the engine exhibited by Quillacq & Co., shows the arrangement perfectly. It is also shown in Fig 40.

The two nuts E E′ press upon the two levers L L′. The motion of translation of one nut is communicated to the side-lever L, and thus displaces the connecting-link of the expansion-gear. When one of the nuts, as E, has reached the end of its travel, and has thus pushed its lever L entirely out, it has produced the maximum of expansion necessary, and this lever is allowed to regain its original position by means of the counterweight T. This produces a full admission, and prepares the second lever L′ for the action of its nut E′. The two levers connected together are relieved simultaneously.

At the succeeding motion, the nuts return to their positions and the nut E′ acts upon the lever L′, in the manner already described.

The irregularity of resistance when heavy loads are to be lifted from a great depth being unfavorable to the action of the engine, it has been attempted to diminish it. In some cases the radius of the hoisting-drum is made very small, in order to compensate the variation in the resistance by an inverse variation of the lever-arm ; this, however, produces rapid wearing of the ropes, and such a number of revolutions is required to raise the load, that the hoisting is done very slowly, and the engine works under unfavorable conditions. In other cases, counterweights are used to regulate this action, but a considerable resistance is thereby added, and sometimes a considerable extra expense. These expedients are evidently imperfect, since their object is to render a force constant which is variable. It is much simpler to allow the irregularity of the resistance to remain, and to apply a force which is correspondingly variable. This is the method which should naturally be first attempted.

Experiment, as the inventor claims, has already decided this question, and the application of the Guinotte system to hoisting engines certainly affords a simpler and more efficient arrangement than the preceding methods.

It seems to the writer somewhat doubtful whether this arrangement would obtain favor with either engineers or builders in the United States. It is, however, stated that the engines fitted with it are very economical in their consumption of fuel, and many European engineers look upon the device with great favor.

83. The SOCIÉTÉ GÉNÉRAL D'EXPLOITATION DES CHEMINS DE FER, of Turbize, exhibited a fine-looking locomotive, which, however, does not require special notice.

The most remarkable engine was that of CARELS, of Ghent, shown in the accompanying plate, Fig. 41. This was a six-wheeled coupled passenger-locomotive, in which the steam-cylinder is mounted above the wheels in the horizontal line, and drives through a vertical working-beam, 3 feet 7 inches between end centers. This arrangement, which was many years ago proposed both in the United States and Great Britain, is here attributed to M. Belpaire, the distinguished inspector-general of the Belgian railways. It is claimed, and probably correctly, to give much greater steadiness at high speeds in consequence of the counterbalancing of the reciprocating parts thus secured. It is also considered to have important advantages in bringing the cross-head and other parts higher above the rail, where they will be less exposed to injury by dirt and dust, and where they are directly under the eye of the fireman, and where also they are accessible for oiling at any time. In this engine greater care has been taken than is usual with European builders to equalize the weights upon the several axles. None seem to have succeeded as well as our own manufacturers. The valve of each cylinder is driven from the cross-head of the opposite engine. The finish of the engine was not remarkably good.

84. RUSSIAN AND ITALIAN LOCOMOTIVES.—Russia and Italy exhibited locomotives. The Russian engines are extremely creditable in every respect, and are very nearly equal to those of the British constructors, from whose designs they seem to have been copied. The Italian engines,

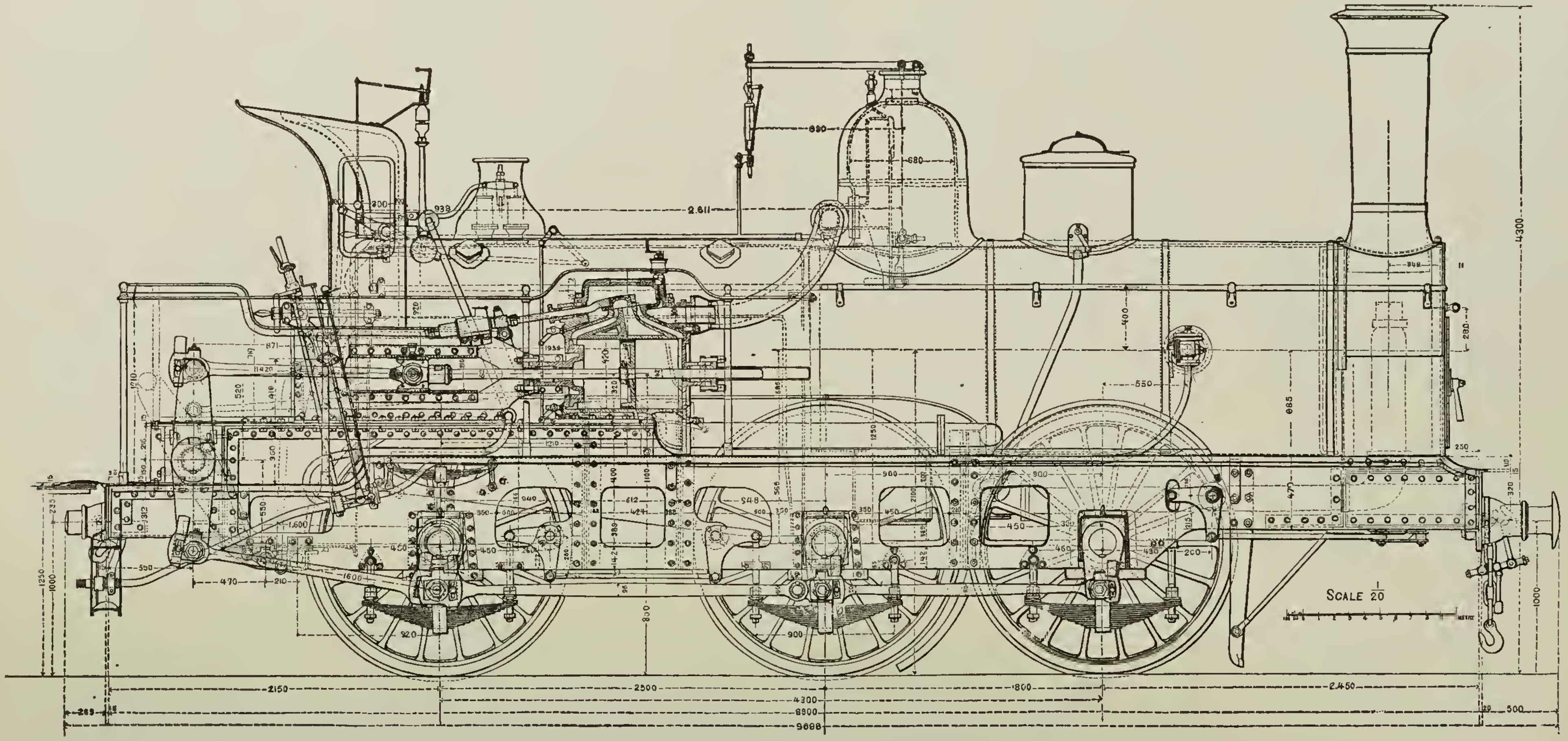


FIG. 41.—Carel's locomotive.

like all of the machinery from that country which came to my notice in the Exhibition, did not compare favorably with the exhibits of other countries. Attempts at original design were very unsuccessful, the materials used were not of superior quality, and the workmanship and finish were invariably inferior.

85. GERMAN AND AUSTRIAN LOCOMOTIVES.—Germany and Austria each exhibited a large collection of locomotives, among which were many of excellent design and fine workmanship.

Bosig, of Berlin, Sigl, of Vienna, Krauss & Co., of Munich, the *Maschinen=fabrik und Eisengiesserei*, Darmstadt, are among the most prominent of the exhibitors.

86. THE STAATS EISENBAHN=GESELLSCHAFT exhibited some exceptionally fine engines. The latter are distinguished by the substitution, to some extent, of wrought for cast iron in parts usually constructed of the latter material, and by the use of "hydraulic forgings."

The Austrian "*Staats Eisenbahn=Gesellschaft*" issued to members of the International Jury a very interesting collection of lithographed outline-drawings of the locomotives built for the Austrian railroads at their works during the past thirty-five years, which supplemented well the very excellent exhibit made by them at the *Ausstellung.*

87. This locomotive-building establishment was founded in the year 1839, under the directorship of Herr Mathias von Schönerer. There was then no other iron-works and foundery in Vienna. The first locomotive was built from American designs, as shown in the accompanying plate, Fig. 42, (Type 1,) and was first placed on the road in 1841, at the opening of the Vienna and Gloggnitz Railroad.

In 1855 the works were enlarged under General-Director Jacquse Maniel, and under his direction were built over fifty different styles of engines. A freight-engine with six coupled drivers was built in 1846. An eight-wheeled engine was built in 1855, and exhibited at Paris. The play given the rear driving-axle of this engine permitted it to pass around sharp curves with a facility which was then considered remarkable.

A locomotive was exhibited which was built in 1870, the thousandth engine built by this company. It had been in service three years, and was in excellent order.

The express-engine Duplex, exhibited in the same collection, was a four-cylinder engine, which was placed in the London Exhibition of 1862. A ten-wheeled locomotive, the Steyerdorf, was said to be capable of readily passing the shortest curves on the Austrian roads. It had been exhibited both at London in 1862 and in Paris in 1867.

88. The accompanying sketches (Figs. 42–47) are copied from those furnished the jury, and the dimensions given with each will enable the experienced builder to read all important particulars at a glance. This collection illustrates the gradual change of style and dimensions taking place decennially from the date of the erection of these works to the present time.

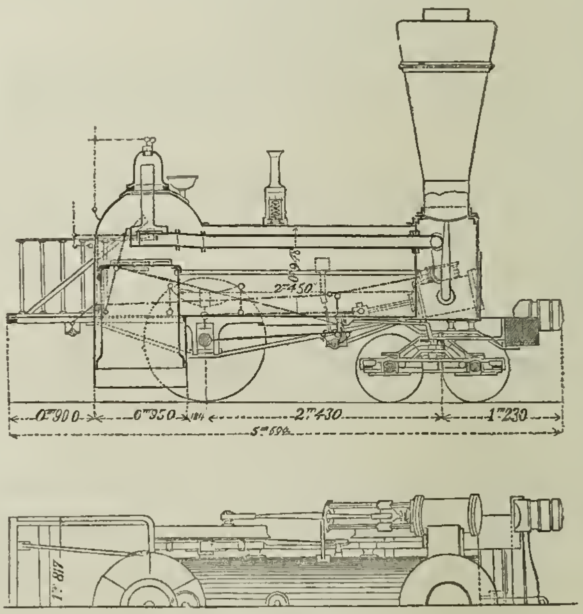


FIG. 42.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 1, *built* 1840.

Diameter of driving-wheels, meters	1.264
Diameter of leading-wheels, meters	0.790
Wheel-base, meters	2.845
Diameter of boiler, meters	0.048
Thickness of boiler-shell, meters	0.009
Pressure in atmospheres	5.5
Number of tubes	75
Diameter of tubes, meters	0.052
Length of tubes, meters	2.450
Area of tubes, surface, square meters	30.4
Total area of heating-surface, square meters	33.5
Total area of grate-surface, square meters	0.74
Weight on driving-wheels, kilograms	10,510
Weight of engine, kilograms	16,805
Weight of engine empty, kilograms	14,560
Extreme length, meters	5.694
Extreme breadth, meters	2.250
Extreme height, meters	3.025

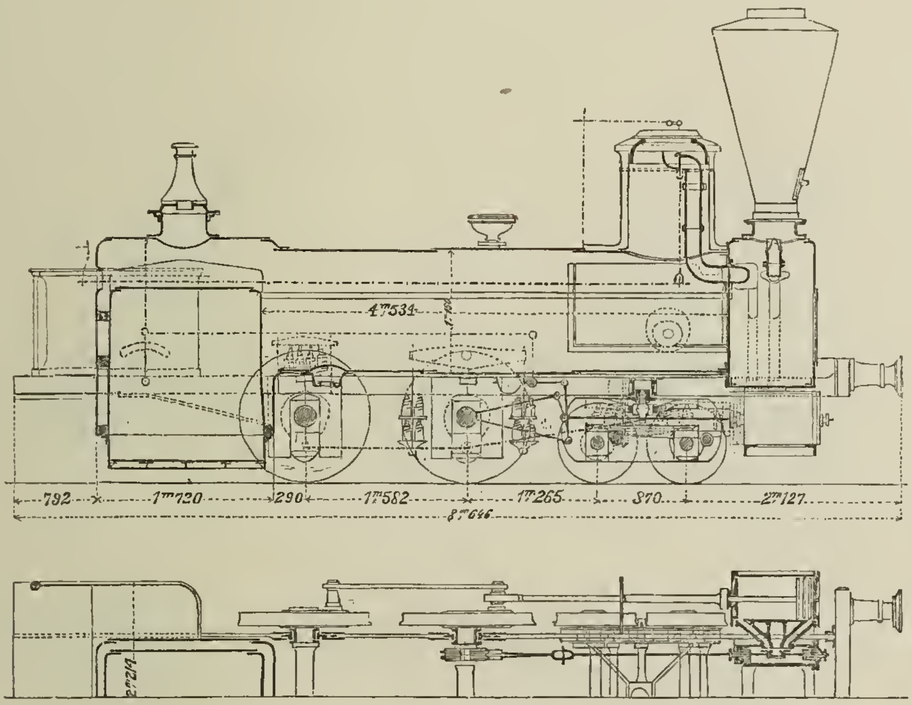


FIG. 43.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 12, *built* 1850.

Diameter of driving-wheels, meters	1.264
Diameter of leading-wheels, meters	0.791
Wheel-base, meters	3.747
Diameter of boiler, meters	1.160
Thickness of boiler-shell, meters	0.013
Pressure in atmospheres	5.5
Number of tubes	134
Diameter of tubes, meters	0.052
Length of tubes, meters	4.534
Area of tubes, surface, square meters	100.5
Total heating-surface, square meters	108.5
Total grate-surface, square meters	1.5
Weight on driving-wheels, kilograms	9,240
Weight of engine, kilograms	29,120
Weight of engine empty, kilograms	26,320
Extreme length of engine, meters	8.676
Extreme breadth of engine, meters	2.425
Extreme height of engine, meters	4.557

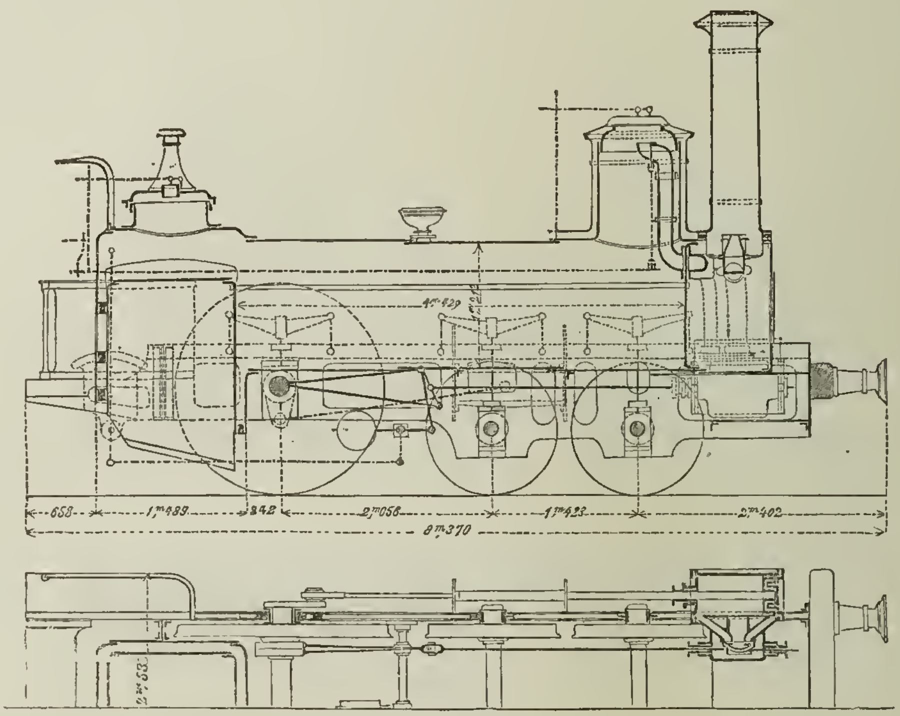


FIG. 44.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 32, *built* 1861.

Diameter of driving-wheels, meters	2.055
Diameter of leading-wheels, meters	1.264
Wheel-base, meters	3.479
Diameter of boiler, meters	1.212
Thickness of boiler-shell, meters	0.013
Pressure, in atmospheres	8
Number of tubes	160
Diameter of tubes, meters	0.052
Length of tubes, meters	4.429
Area of tubes, surface, square meters	117.2
Total heating-surface, square meters	125.0
Total grate-surface, square meters	1.4
Weight on driving-wheels, kilograms	12,500
Weight of engine, kilograms	32,200
Weight of engine empty, kilograms	29,600
Extreme length of engine, meters	8.370
Extreme breadth of engine, meters	2.681
Extreme length of engine, meters	4.653

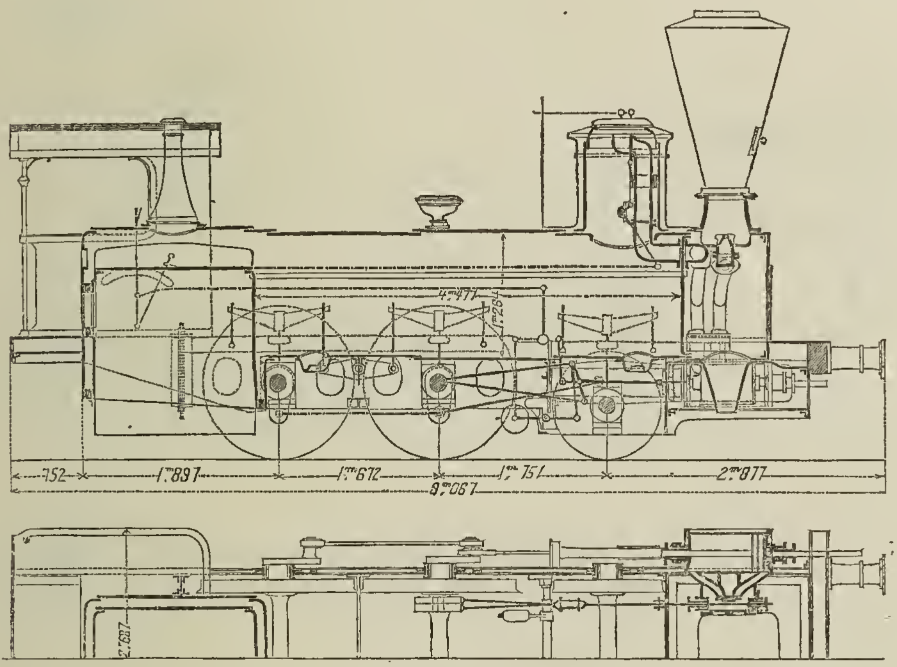


FIG. 45.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 49, *built* 1869. *Hall's system.*

Diameter of driving-wheels, meters	1.580
Diameter of leading-wheels, meters	1.106
Diameter of boiler, meters	1.264
Thickness of boiler-plates, meters	.011
Pressure in atmospheres	9
Number of tubes	162
Outside diameter, meters	0.052
Outside length, meters	4.477
Area of tube-heating-surface, square meters	120
Total heating-surface, square meters	229
Total grate-surface, square meters	1.925
Weight on axles, kilograms	35,000
Extreme length of engine, meters	9.067
Extreme breadth of engine, meters	2.687
Extreme height of engine, meters	4.583
Wheel-base of engine, meters	3.423

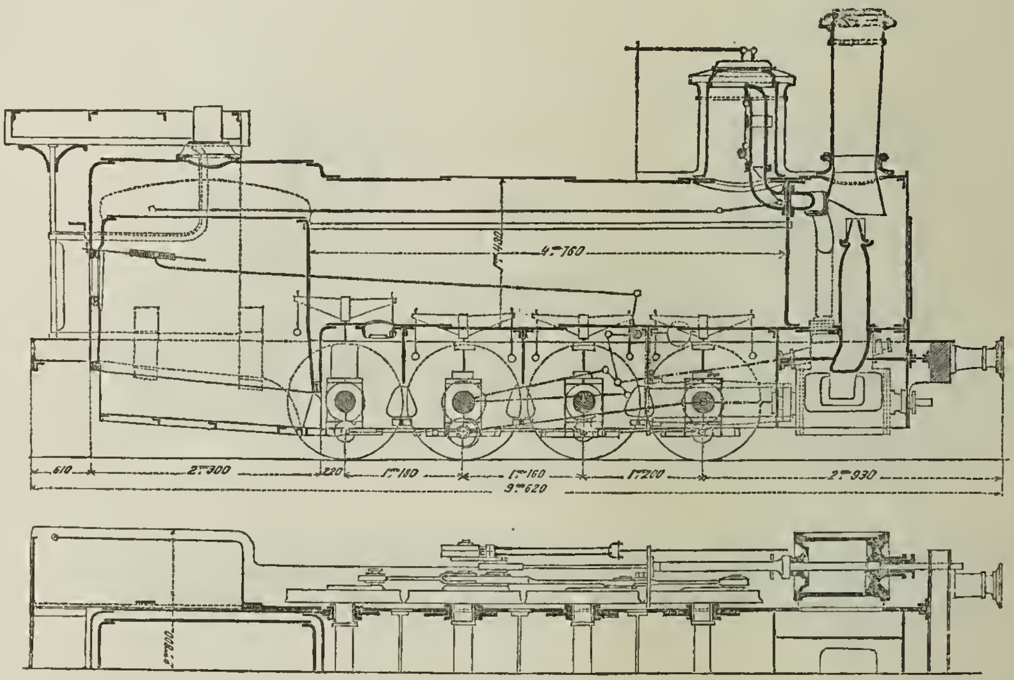


FIG. 46.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 51, *built in* 1871.

Diameter of driving-wheels, meters	1.106
Wheel-base, meters	3.560
Diameter of boiler, meters	1.430
Thickness of boiler-shell, meters	0.015
Pressure in atmospheres	9
Number of tubes	205
Outside diameter of tubes, meters	0.052
Length of tubes, meters	4.760
Area of surface of tubes, square meters	159.3
Total heating-surface, square meters	170
Total grate-surface, square meters	2.16
Total weight on drivers, kilograms	50,750
Weight of engine empty, kilograms	45,191
Extreme length of engine, meters	9.620
Extreme breadth of engine	2.800
Extreme height of engine	4.400

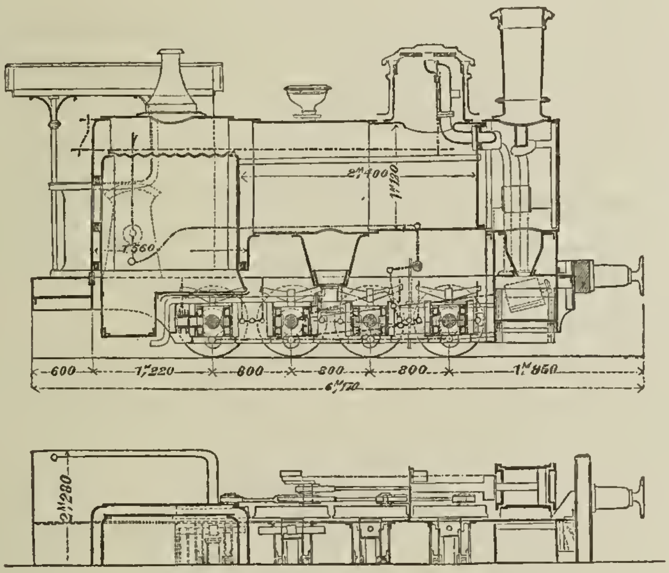


FIG. 47.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 54, *built in* 1873. *Haswell's system.*

Diameter of driving-wheels, meters	0.720
Wheel-base, meters	2.400
Diameter of boiler, meters	1.120
Thickness of boiler-shell, meters	0.010
Pressure in atmospheres	12
Number of tubes	102
Outside diameter of tubes, meters	0.052
Area of surface of tubes, square meters	40.
Total heating-surface, square meters	46.
Grate-surface, square meters	1.40
Weight on each axle, kilograms	5,000
Weight on axles, total, kilograms	20,000
Weight of engine empty, kilograms	18,000
Length of engine over all, meters	6.170
Breadth of engine over all, meters	2.210
Height of engine over all, meters	3.500

The establishment is now under the direction of Mr. J. Haswell, the distinguished engineer who has succeeded so well in the introduction of the hydraulic press in forging.

Mr. Haswell states that in 1872 the works turned out ninety-two locomotives, making a total of one thousand two hundred and forty-two since the commencement in 1840.

89. CHARACTER OF CONTINENTAL WORK.—By far the finest work of continental mechanics is seen in this splendid collection of the locomotives built in Germany and Austria. The designs are usually intermediate between those of British and of American builders. The general design is more nearly that of the former. The truck, or "bogie," under the forward end of the boiler is rarely seen. The American system of "equalizers" is used to a considerable extent, and often with much skill. The "cab" is much more frequently met with on continental than on English-built engines, and is very frequently given the form and proportions of that detail as made in America.

90. The frames of these engines, British as well as continental, are not made of square bars of forged iron as with us, but are cut out of heavy rolled plate, usually about thirty millimeters (1.2 inches) in thickness. All but one of the engines exhibited have outside cylinders. The valves in many instances are driven by eccentrics, placed outside the crank-pin and without the intervention of rock-shafts.

91. The boilers of some of the leading examples are of what is called in Europe the "Belpaire" style, in which the fire-box end is enlarged, (Fig. 48,) somewhat as it is frequently done in the United States, to obtain a wider grate and a higher steam-space above the crown-sheet. Instead, however, of making this portion semi-cylindrical, as we are accustomed to seeing them, tops and sides are made flat, forming a rectangular box, as seen in the plate, with rounded corners. These flat surfaces are strongly stayed, and no difficulty seems to have been yet observed in making or in working them. The connection between this enlarged part of the boiler and the remaining part of the shell is not, as in the United States, made by a conical portion which tapers from one end, where it is riveted to the fire-box end, to the other which is riveted to the cylindrical part of the boiler. In these boilers the connection is made by a single sheet of heavy plate, which has a large hole cut through it and a flange turned all around its circumference to take the sheets of the small part of the shell, while the outer edge is flanged and has such a shape that it may be riveted to the sheets forming the fire-box. This makes a very strong connection between the two parts, and at the same time forms an effective expansion-joint. It evidently can only be done where good iron can be found and good flanges made. Should this method, on the whole, prove superior to that in use in the United States, however, our manufacturers will find here no obstacle to its introduction.

Staying the fire-box top from the crown-sheets has the advantage of

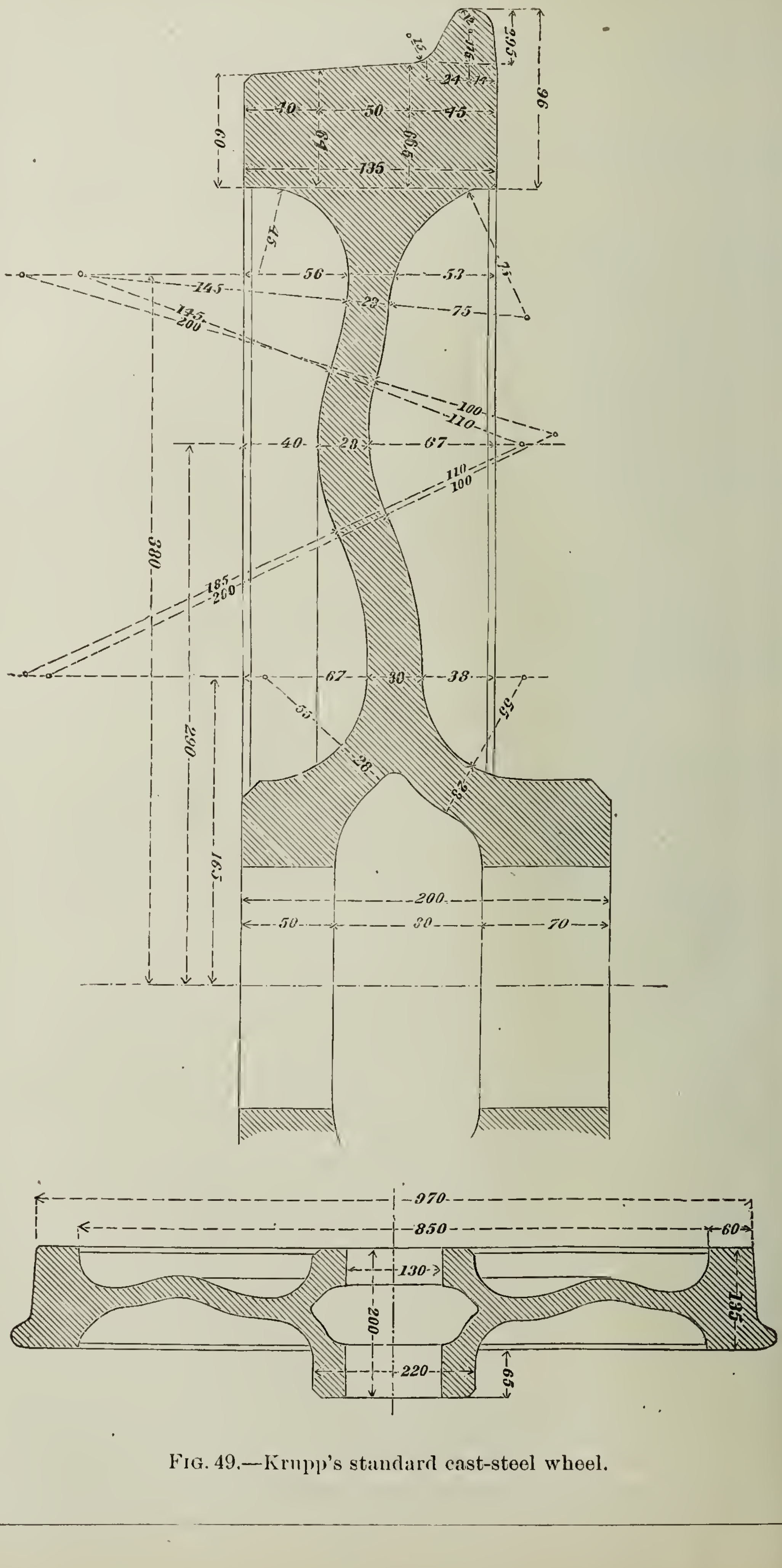


FIG. 49.—Krupp's standard cast-steel wheel.

doing away with the objectionable girder-stays, which are the usual supports of the crown-sheets in American locomotives.

92. The pressure of steam allowed on these boilers is usually eight or nine "atmospheres," as pressures are reckoned in Europe. The boilers have a greater "factor of safety" than we are accustomed to adopt in the United States, a point in European practice which it might be well for us to copy.

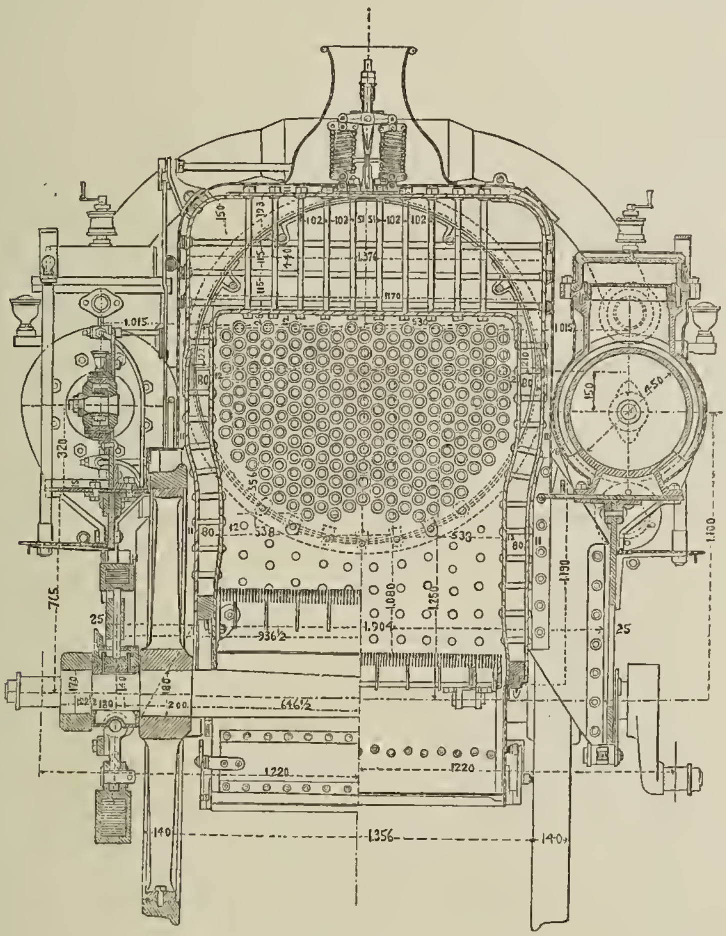


FIG. 48.—Belpaire's fire-box.

93. The riveting is usually done by the riveting-machine, which, *properly used**, does much better work than can be done by hand, making the seam both lighter and stronger. The rivets are usually snap-headed, and, when made by hand, are headed-up by blows of a heavy hammer on the head of a forming-tool. In some cases the calking of seams had been carelessly done, as was shown by the marks of the calking tools on the sheet under the lap.† The serious results which follow so frequently from the creation of furrows and grooves along these lines are well known to all intelligent builders, and the manufacturers of these engines were seriously in fault in permitting these boilers to be thus injured, and of a great

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*Probably the best form of riveting-machine yet produced is that of the Providence Steam-Engine Works, at Providence, R. I., in which one die closes the laps, and another, by an indepedent steam-piston, then heads-up the rivets.

†The "concave" system of calking introduced in the United States recently by Mr. Connery at the Baldwin Locomotive Works and elsewhere is, in the opinion of the writer, a vast improvement upon the ordinary method.

oversight in sending such evidence of carelessness to be exhibited at Vienna.

94. MATERIALS—SOFT STEEL *vs.* IRON.—The material used for running-gear and valve-motion, and not infrequently for the boiler also, is becoming quite universally "low steel," or, as it should more properly be called, homogeneous iron. The irons of commerce, which are usually sold as iron, contain barely a trace of carbon, and invariably contain also a certain amount of cinder, which cannot be entirely removed in the ordinary process of puddling and rolling or hammering, even with the most careful manipulation. They are, therefore, weaker than a pure metal would be, and have a fibrous structure, which is caused by the drawing down of the masses of impurity in the puddle-ball into lines, or striæ, which prevent the acquisition of that homogeneous character which is always desired in good material. These "low steels" are usually made either by the Bessemer or the Siemens-Martin process, and, taking form in the ingot-mold, into which they are poured when liquid, the cinder is separated, floating to the top, and leaving the metal quite free from it and nearly pure. These steels also contain from one-quarter to one-half per cent. carbon, an amount which strengthens the metal greatly without conferring upon it any steely quality. The elastic limit is raised somewhat, and the ductility of the metal is practically equally great. The unworked ingot is liable to exhibit a considerable degree of porosity in consequence of the liberation of gas, while the molten mass is solidifying whenever the spiegelisen, employed as a conveyor of carbon, is not sufficiently rich in manganese. This porosity, although less objectionable than the condition of malleable or wrought irons, in which the cavities are filled with impurities, is still a defect, which, when the ingots are worked down into pieces of smaller section, is seen in the formation of a fibre, which becomes perceptible, however, only when the metal is examined by some exceptionally delicate method of test. Strain-diagrams, produced by the autographic-recording testing-machine, exhibit these characteristics very completely.

The metal here described has usually an elastic limit nearly 50 per cent. higher than that of common iron, and its ultimate tensile strength reaches 70,000 or 80,000 pounds per square inch. It stretches, if of good quality, 25 per cent. before breaking. It is claimed, by many manufacturers, that it can now be obtained quite as uniform in quality as wrought iron, and at prices which make it good policy to use it whenever possible. Its homogeneousness in quality and structure are considered quite as important qualities as its strength, high elastic limit, and ductility. It is the best material now available for use where a tough, strong, ductile material is required, as whenever heavy shocks are to be sustained.

Where the quality desired is durability under heavy load and abrasion, as is the case with rails, the high elastic limit constitutes its distinguishing merit. The metal should always be carefully chosen with

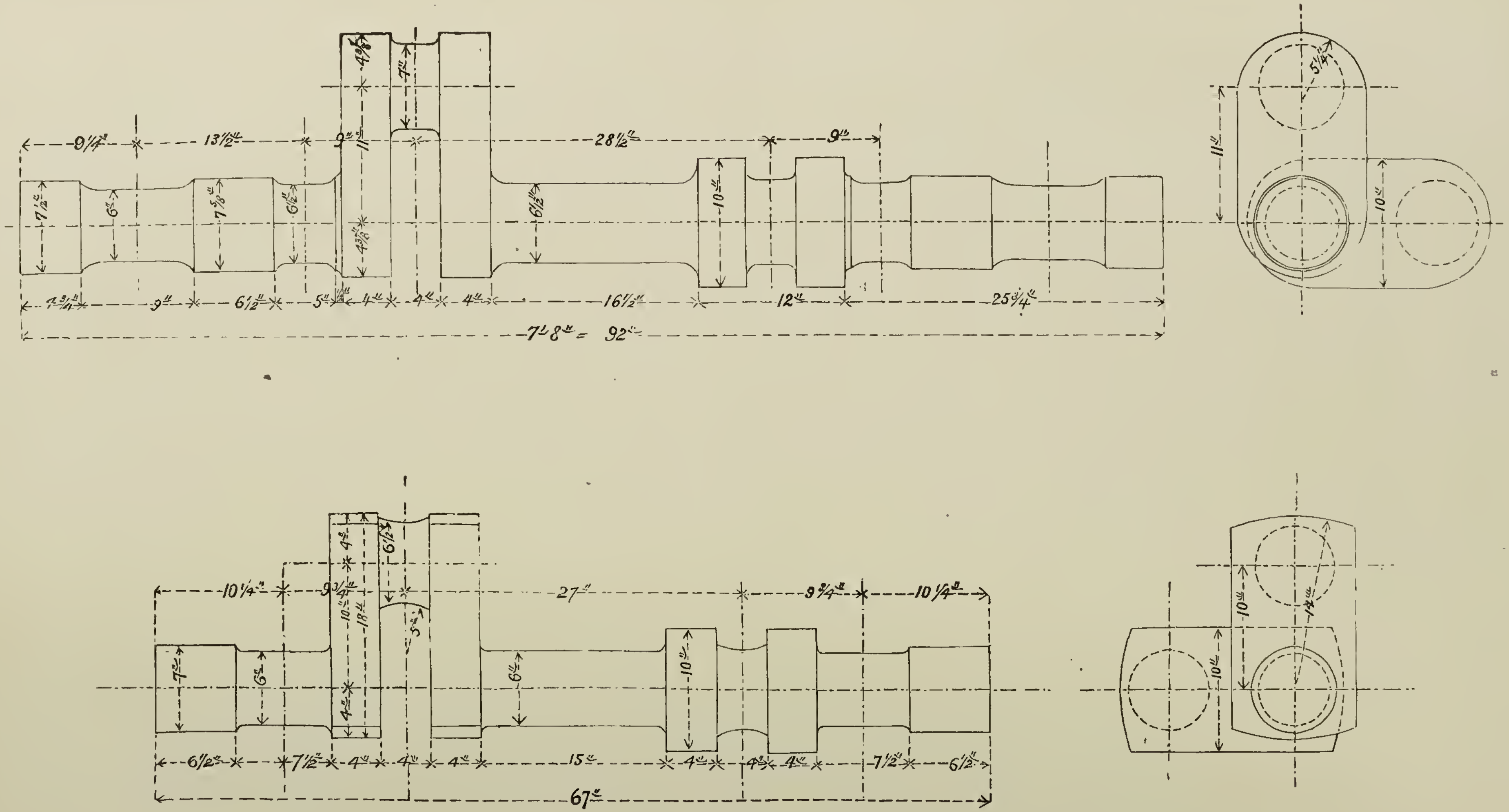

FIG. 50.—Krupp's driving-axles.

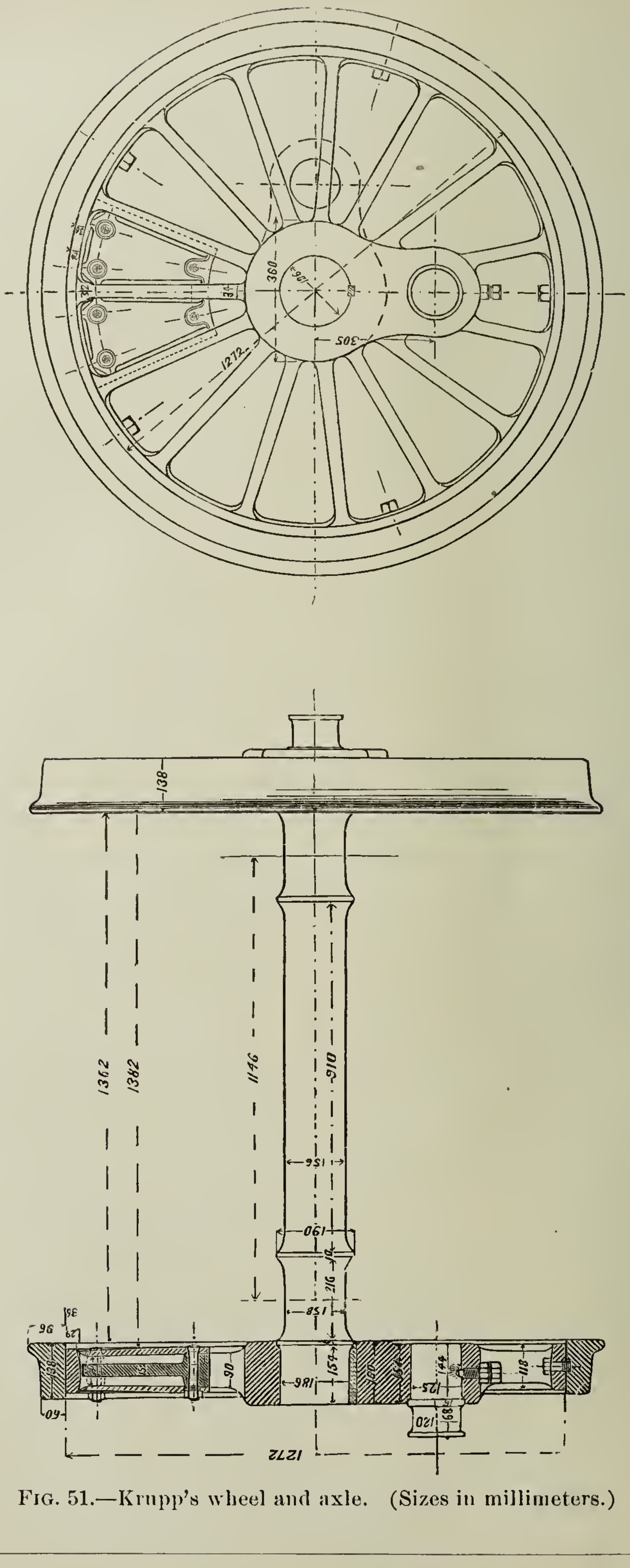

FIG. 51.—Krupp's wheel and axle. (Sizes in millimeters.)

reference to its intended use. By changing the dose of carbon it is made fit for every purpose.

Another valuable quality of the low steels which should not be overlooked is that of taking a beautifully fine finish.

95. EUROPEAN RAILROAD WHEELS.—The driving-wheels, as well as the other wheels of locomotives, are invariably forged. A cast-iron driving-wheel is never seen in Europe, and European builders seem quite unable to believe that they can be used with safety. They regard American practice in this particular as simply illustrating that recklessness which is looked upon by them very generally as one of the most remarkable traits of our national character.

96. In the exhibit of Krupp, of Essen, were some fine specimens of locomotive work, of which scale-drawings are here shown, (Figs. 49, 50, 51, 52,) with dimensions given. They serve to illustrate both the character of the work done at Essen and the proportions adopted for these details; also the extent to which steel is applied in locomotive building. The driving-axle (Fig. 50) is a fine piece of work; the material is free from flaw or blemish, and the finish is remarkably fine. The sketch of the driving-wheel and axle (Fig. 51) illustrates the proportions adopted for standard work in this part of Europe, and the crank and eccentric (Fig. 52) form an example of an exceptionally awkward piece of work excellently well done.

97. CONCLUSIONS.—An examination of this collection, illustrating as it does the best contemporary European practice, has, after all, revealed but little that is new to American engineers. The novelties are few in number, and are not usually of a character which will be likely to be imitated.

The changes now going on in transatlantic practice are principally in minor details, and in the introduction of better material. Such changes of design as are noticed are usually in a direction in which our own builders have already gone in advance.

98. Forty years ago Robert Stephenson, in a letter to Robert L. Stevens,* wrote: "I am sorry that the feeling in the United States in favor of light railways is so general. In England we are making every succeeding railway stronger and more substantial. * * * Small engines are gradually losing ground, and large ones are daily demonstrating that powerful engines are the most economical." This is still the direction of change, although it is far less rapid than formerly. Stephenson incloses in the letter above referred to a sketch of an engine weighing *nine tons*, and capable, as he stated, "of taking one hundred tons gross load at the rate of sixteen or eighteen miles an hour on a level." The largest locomotive at Vienna weighed *seventy tons*, and it is capable of drawing a load of probably 1,000 tons, at a speed of thirty miles an hour.

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* Preserved in the "Relic Corner" of the lecture-room of the writer at the Stevens Institute of Technology.

For many years locomotives have remained practically unchanged in all except size and in the form and proportions of the minor details.

There is undoubtedly good reason for this fact, and it is not impossible that it may continue to be the fact for an indefinite period, although no thoughtful engineer would be surprised were some new discovery or some unanticipated invention to suddenly revolutionize locomotive practice at any time. The locomotive is a simple machine, and the essential requisites of strength, lightness, and compactness are insuperable obstacles to such a multiplication of parts and range of modification of form as are permissible with the stationary, or even the marine, engine, and the opportunities offered for the exercise of inventive skill and for the application of frequently desirable devices are greatly restricted. The modification of size to suit various loads, and of type to adapt the machine to various speeds and to various special kinds of work are the directions in which designing is afforded an open field. In construction, good material and good workmanship are becoming more generally understood and more universally adopted.

In none of the engines shown at Vienna is seen that flexibility and consequent ease of traction on the smoothest of European railways, as well as on the roughest of our American roads, which is a common characteristic of American locomotives. Improvement is evidently taking place, although slowly, in feeding-apparatus, in the adoption of continuous breaks, in the use of metallic packing, and in the substitution of coal for the more expensive coke formerly exclusively used.

99. The use of steel has become more common in Europe than in America, but it is, nevertheless, now becoming rapidly introduced into the United States. Its use is becoming very general in fire-boxes, although the frequent cracking of plates which contain too high a percentage of carbon is retarding it.

The metal, if given barely sufficient carbon to enable the steel-furnace heat to melt it, will rarely be found to give trouble. The less the dose of carbon, and the nearer the metal becomes in character a homogeneous iron, the better will it serve this purpose.

(Sizes in millimeters.)

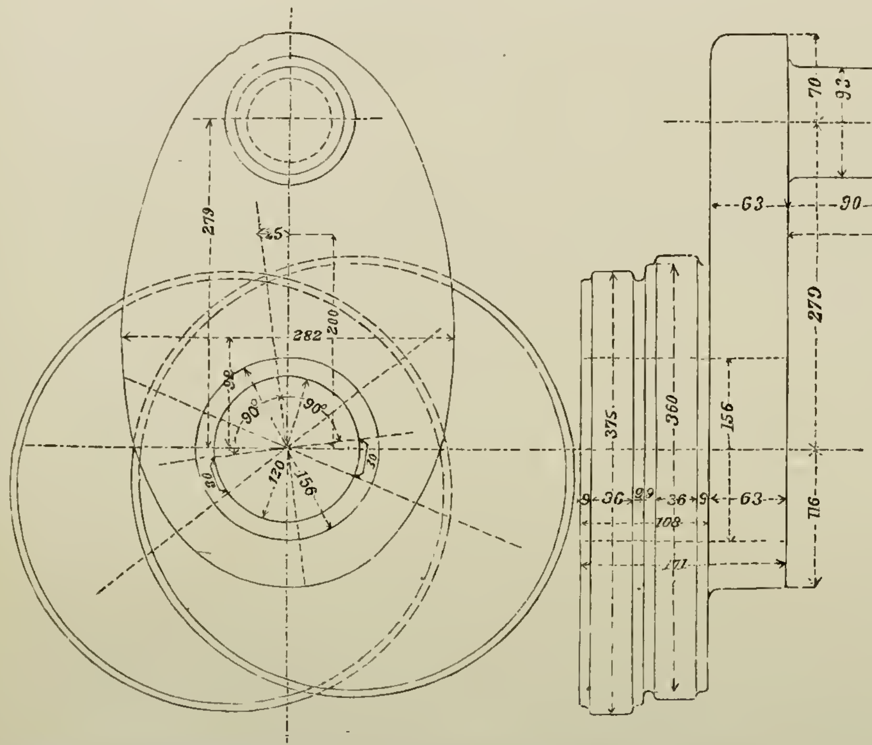

FIG. 52 *a.*—Driving-crank, without eccentric, for the Schweizer Nord-Ost. Bahn.

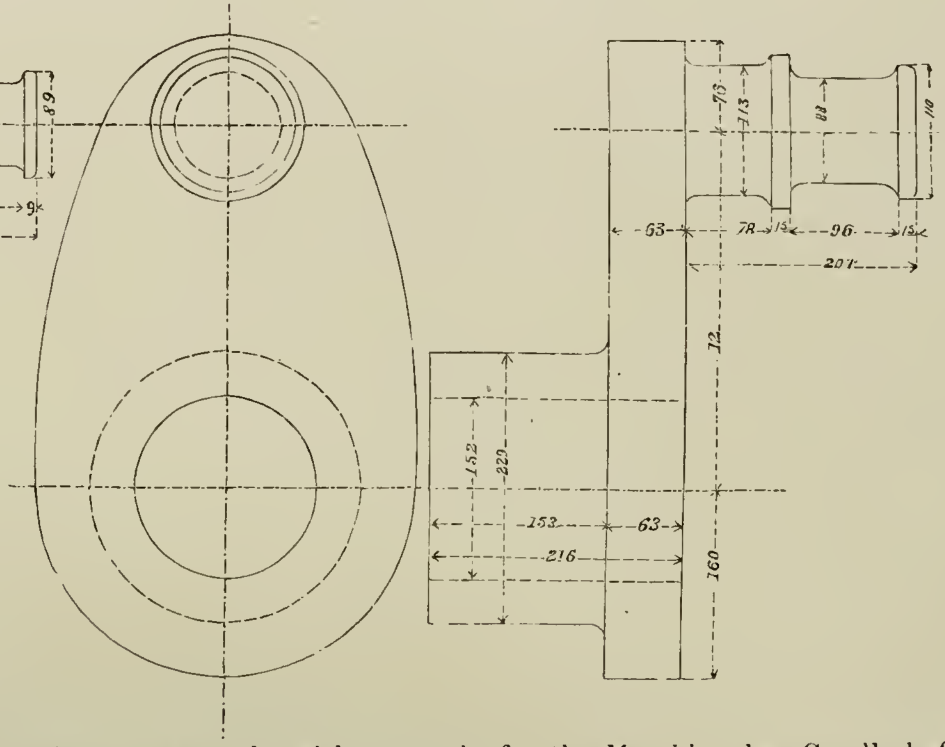

FIG. 52.—Krupp's driving-crank, with eccentric, for the Maschinenbau-Gesellschaft, Carlsruhe.

PRINCIPAL DIMENSIONS OF LOCOMOTIVE-ENGINES AT THE VIENNA EXHIBITION.

Reference number.	Maker's name and address.	Class of engine.	Whether tank or tender.	Gauge.	WHEELS. Number of wheels.	Number of wheels coupled.	Diameter of coupled wheels.	Diameter of wheels not coupled.	WHEEL-BASE. Total wheel-base.	Length rigid wheel base.	CYLINDERS. Position.	Diameter.	Stroke.	Position of valve-gear.	TUBES. Number.	Length.	Diameter.	HEATING-SURFACE. Tubes outside.	Fire-box.	Total.	Fire-grate area.	WEIGHT OF ENGINES. Empty.	In working order.	On coupled wheels in working order.
	ENGLAND.			*Ft. In.*			*Ft. In.*	*Ft. In.*	*Ft. In.*	*Ft. In.*		*In.*	*Ft. In.*			*Ft. In.*	*In.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Tons.*	*Tons.*	*Tons.*
1	Henry Hughes & Co., Loughborough	Contractors'	Tank	4 8½	4	4	2 6	......	4 6	4 6	Outside	8½	1 3	Inside	......	......	......	......	......	233	5	8	10	10
2	Fox, Walker & Co., Atlas Engine Works, Bristol	Mixed	do	3 6	6	4	3 0	2 3	11 0	6 0	do	10	1 6	do	96	8 2	1¾	359	47.16	4 6.16	7.4	14.75	18.25	12.5
	FRANCE.																							
3	Schneider et Cie, Creuzot	Goods	Tender	4 8½	8	8	3 11½	......	12 8⅛	......	Outside	21½	2 0	Outside	270	16 1	2	2121.3	116.7	2238	20.4	47.4	53.9	53.9
	ITALY.																							
4	Societa nazionale d'industrie meccaniche in Napoli	Goods	Tender	4 8½	6	6	4 3	......	......	......	Outside	......	......	Inside	......	......	......	......	......	......	......	......	......	......
	BELGIUM.																							
5	Société John Cockerill, Seraing	Goods	Tender	4 8½	6	6	......	......	......	......	Outside	......	......	Inside	......	......	......	......	......	......	......	......	......	......
6	do	Contractors'	Tank	......	4	4	......	......	......	......	do	......	......	do	......	......	......	......	......	......	......	......	......	......
7	Société de Couillet, Directeur-General M. Eugene Smits	Passenger	Tender	4 8½	6	4	......	......	......	......	do	......	......	Outside	......	......	......	......	......	......	......	......	......	......
8	Société générale d'exploitation des chemins de fer, Turbize	do	do	4 8½	6	4	......	......	......	......	do	......	......	do	......	......	......	......	......	......	......	......	......	......
9	C. L. Carels, G and	do	do	4 8½	6	6	......	......	14 1¼	......	do	......	......	Inside	......	......	......	......	......	......	......	......	......	......
	GERMANY.																							
10	A. Borsig, Berlin	Passenger	Tender	4 8½	6	4	6 5	4 1	14 6	7 9	Outside	16½	1 10¾	Inside	......	......	......	......	......	......	......	......	......	......
11	Maschinenfabrik, Esslingen, Director Emil Kessler	do	do	4 8¼	6	4	6 3	3 3½	13 6	......	do	15⅝	2 0⅞	do	155	12 10¾	2½	1028.3	85.2	1113.5	16	28.75	32	24.5
12	Maschinenbau-gesellschaft Carlsruhe, Carlsruhe	Mixed	Tank	2 7	4	4	2 2¾	......	4 8⅝	4 8⅝	do	9⅞	1 1	Outside	......	......	......	......	......	246	......	9	11.1	11.1
13	Krauss & Co., Munich	Goods	do	4 8½	6	6	3 10⅝	......	10 4⅜	10 4⅜	do	16 1-16	2 0⅞	do	169	13 1½	1⅞	1185.7	83.9	1269.6	16.4	26.5	38	38
14	do	General service	do	4 8½	4	4	3 2 3-16	......	8 0¼	8 0¼	do	11⅜	1 9¼	do	127	10 11⅝	1⅝	625.1	48.4	673.5	9.6	19	24	24
15	do	Contractors'	do	2 5	4	4	1 10 7-16	......	3 7⅞	3 7⅞	do	6⅜	0 11⅞	do	80	6 2¾	1½	181.8	13.9	195.7	3.2	5.2	6.3	6.3
16	T. A. Maffei, Hirschau, near Munich	Goods	Tender	4 8½	6	6	4 1	......	10 5	10 5	do	19½	2 2	......	181	13 5⅛	2 7-16	1320	80	1400	16.9	32.5	36.5	36.5
17	Henschel & Son, Cassel	do	do	4 8½	6	6	4 2¼	......	10 0	10 0	do	17½	2 0⅝	......	200	14 1⅛	1¾	1337	86.5	1423.5	15.8	33.18	37.6	37.6
18	Berliner Maschinenbau-Actien-Gesellschaft, formerly L. Schwartzkopff	General service	Tank	4 8½	6	4	4 6	3 0	12 2 3-16	......	do	16½	1 10	Inside	156	......	1⅞	730	69.8	799.8	13.2	28.5	35.1	26.1
19	Stettiner Maschinenbau-Actien-Gesellschaft Vulcan, near Stettin	Passenger	Tender	4 8½	6	4	5 0	3 2	14 5¼	8 6⅜	do	16½	1 11⅝	Outside	188	12 1¾	1¾	957.6	75.3	1032.9	17.7	......	35.2	23
20	F. Wöhlert, Berlin	Goods	Tank	4 8½	6	6	4 7½	......	12 4	12 4	do	17½	2 0¾	Inside	......	10 8	......	......	......	......	13.7	......	......	......
21	Hannover'sche Maschinenbau-Actien-Gesellschaft, formerly G. Esterhoff, Linden, near Hanover	Passenger	Tender	4 8½	6	4	6 0	3 6	14 0	14 0	do	16	1 10	do	190	11 8¼	2	1163	85.7	1248.7	20	30.9	......	......
22	do	Goods	do	4 8½	6	6	4 3	......	10 6	10 6	do	17	2 0	do	203	14 4⅛	1 13-16	1327.2	76.6	1403.8	19.8	......	......	......
23	Sächsische Maschinenfabrik zu Chemnitz, formerly Richard Hartmann, Chemnitz	do	do	4 8½	8	8	3 7½	......	11 9	......	do	17⅝	1 10⅞	......	......	......	......	1523.4	101.4	1624.8	18.8	......	42.25	42.45
24	Maschinenfabrik und Eisengiesserei, Darmstadt	General service	Tank	4 8¼	4	4	3 3	......	6 6½	6 6½	do	12	1 7	Outside	......	......	......	......	......	......	......	......	......	......
25	do	Contractors'	do	3 1⅜	4	4	2 2	......	4 7½	4 7½	do	10	1 3	do	......	......	......	......	......	......	......	......	......	......
26	Harzer Werke zu Rübeland und Zorge, Zorge, Harz	do	do	4 8¼	4	4	1 11⅝	......	5 1⅞	......	do	7⅞	0 9⅞	do	104	......	2	......	......	116.7	......	7.5	......	......
27	Koechlin & Co., Mulhouse	Express	Tender	......	6	4	6 7⅛	4 5¼	15 3	15 3	do	17	2 0⅝	do	191	11 5¾	1 49 64	1016.6	97.2	1113.8	22	......	......	......
	AUSTRIA.																							
28	Maschinen-Fabrik der K. K. Oester, Staatseisenbahn-Gesellschaft	Goods	Tender	3 1	8	8	2 4½	......	7 10½	7 10½	Outside	......	......	Outside	......	......	......	......	......	......	......	......	......	......
29	do	do	do	......	8	8	3 10	......	12 4½	12 4½	do	......	2 2	Inside	......	......	......	......	......	......	......	......	......	......
30	do	do	do	......	6	6	3 6	......	9 5	9 5	do	......	2 0	Outside	......	......	......	......	......	......	......	......	......	......
31	do	General service	Engerth system	......	10	4	5 3	3 2	27 4	8 7½	Inside	......	1 11	Inside	......	......	......	......	......	......	......	......	......	......
32	Maschinen-Fabrik der K. K. priv. Oester. Staatseisenbahn-Gesellschaft, Resicza	Contractors'	Tank	3 1 5-16	4	4	2 3	......	4 8	......	Outside	9½	1 0	Outside	64	6 2	2	231	29	250	......	......	......	......
33	Wiener Locomotiv-Fabriks-Actien Gesellschaft Florisdorf, near Vienna, Director Bernhard Demmer	General service	Tender	4 8½	8	4	5 1	3 2	10 4	5 5½	do	15½	2 0	do	......	......	......	......	......	......	......	......	......	......
34	G. Sigl, Neustadt, Vienna	Goods	do	4 8½	8	8	3 7½	......	11 8½	......	do	19 11-16	2 0	do	205	15 7¼	2 3-64	1704	115	1819	26.24	44.5	51	51
35	do	Passenger	do	4 8½	6	6	5 2¾	......	13 8¾	......	do	16½	2 0⅞	Inside	174	14 1¼	2	1291.12	80.7	1372.4	18.29	32	36	......
36	do	Goods	do	4 8½	8	8	3 6⅛	......	11 9¾	......	do	20½	2 0	do	223	14 3½	2 3-64	1823.9	105.4	1939.3	21.52	41	46	46
37	do	Express	do	4 8½	8	4	6 2⅞	......	17 7	......	do	16⅓	2 0⅞	Outside	179	11 7¾	1 31-32	1073.8	85	1158.8	17.22	33.5	37.5	23
38	G. Sigl, Neustadt, Vienna, (exhibited by the K. Kaiser Ferdinand Nordbahn)	Goods	do	4 8½	6	6	4 0	......	10 8	......	do	17	2 2	do	......	......	......	......	......	......	......	......	......	......
39	K. Kaiser Ferdinand Nordbahn	do	do	4 8½	6	4	4 1½	3 1½	11 9	11 9	do	16	2 0	Inside	......	......	......	......	......	......	......	......	......	......
40	K. K. Nord-West-Bahn, (built by Sigl, 1870)	General service	do	4 8½	6	4	5 2	3 1	10 5½	10 5½	do	16	2 2	Outside	......	......	......	......	......	......	......	......	......	......
	HUNGARY.																							
41	M.-K. Allamvasutak Gép és Kocsi-Gyára-Budapesten Zimmermann, F. Teazcate	Goods	Tender	4 8½	6	6	3 10	......	10 5	10 5	Outside	18	2 1	Inside	......	......	......	......	......	......	......	......	......	......
	RUSSIA.																							
42	Great Russian Railway Co., St. Petersburg Warschau Line, St. Petersburg shops	Passenger	Tender	5 0	6	4	......	......	......	......	Outside	......	......	Inside	......	......	......	......	......	......	......	......	......	......
43	do	Goods	do	5 0	6	6	......	......	......	......	do	......	......	do	......	......	......	......	......	......	......	......	......	......

CHAPTER IV.

ROAD-LOCOMOTIVES; TRACTION-ENGINES.

BELGIAN LOCOMOTIVES WITH RUBBER TIRES; ENGLISH TRACTION-ENGINES; HISTORICAL; FOREIGN TRIALS OF ROAD-ENGINES; TRIAL BY THE AUTHOR AT SOUTH ORANGE, N. J.; DEDUCTIONS; TRACTION-FORCE; WORKING TIME; FIRST COST; RUNNING EXPENSES; GOOD ROAD-BEDS ESSENTIAL TO THEIR SUCCESS; ADVANTAGES OF STEAM-TRACTION.

100. BELGIUM ROAD-LOCOMOTIVES.—Several road-locomotives or traction-engines were exhibited in the British section, and one of these machines, fitted with the Thompson India-rubber tires, was entered in the Belgian catalogue. The latter was frequently seen at work, and was driven about the grounds to exhibit its power and speed and its facility of maneuvring. The action of the elastic tire was very interesting, and it was claimed to be durable. The exhibitor stated that it enabled the machine to be used in situations where the usual iron tire refuses to take hold.

101. BRITISH TRACTION-ENGINES.—Messrs. FOWLER, the well-known builders of steam-plows, exhibited a very neat and apparently substantial and effective style of road-locomotive.

Messrs. AVELING & PORTER exhibited a road-locomotive with a crane attached for lifting and transporting loads, and also another engine intended simply for traction. These machines were the most noticeable of this class in the exhibition.

102. HISTORY OF ROAD-LOCOMOTIVES.—The introduction of the road-locomotive, in substitution for horses whenever heavy work is done, is taking place slowly but steadily, so slowly that it seems to attract but little attention, notwithstanding its immense importance.

This movement began more than a century ago. As early as 1759, Dr. Robinson, who was at the time a graduate of the University of Glasgow, and an applicant for an assistant professorship there, and who made the acquaintance of the instrument-maker James Watt, when visiting the workshop of the latter, called his attention to the possibility of constructing a carriage to be driven by a steam-engine.

In 1765 that singular genius, Dr. Erasmus Darwin, whose celebrity was acquired by speculations in poetry and philosophy as well as in medicine, urged Matthew Boulton—subsequently Watt's partner, and just then corresponding with our own Franklin in relation to the use of steam-power—to construct a steam-carriage of which he sketched a set of plans.

A young man named Edgeworth became interested in the scheme, and, in 1768, published a paper which secured for him a gold medal from the Society of Arts. In this paper he proposed railroads on which the carriages were to be drawn by horses, or by ropes from steam-winding engines.

The first actual experiment was made, as is supposed, by a French army officer, Nicholas Joseph Cugnot, who, in 1769, built a steam carriage which was set at work in presence of the French minister of war, the Duke de Choiseul. The funds required by him were furnished by the Comte de Saxe. Encouraged by the partial success of the first locomotive, Cugnot, in 1770, constructed a second, which is still preserved in the *Conservatoire des Arts et Metiers*, Paris.

Watt patented a road-engine in 1784, after he had made the more essential improvements in general design and in the details of his pumping-engine. At about the same time Murdoch completed and made a trial of a model locomotive, driven by a "grasshopper-engine" having a steam-cylinder three-quarters of an inch in diameter and two inches stroke of piston. It is reported to have run six to eight miles an hour.

In 1786 Oliver Evans asked of the Pennsylvania legislature the monopoly of his method of applying the steam-engine in driving flour-mills *and to propelling wagons.* In the same or following year Wm. Symington constructed a working model of a steam-carriage, which may be seen in the patent museum at South Kensington, London.

In 1802 Trevithick and Vivian took out a British patent for a locomotive-engine, and their model is also preserved in the museum of the British patent office.

In 1804 Oliver Evans completed a flat-bottomed boat to be used at the Philadelphia docks, and, mounting it on wheels, drove it by its own steam-engine to the river-bank. He then propelled it down the river, using its steam-engine to drive its paddle-wheels. Evans asserted that carriages propelled by steam would soon be in common use, and offered a wager of $300 that he could build a "steam-wagon" that should excel in speed the swiftest horse that could be matched against it.

In 1821 Julius Griffiths, of Middlesex, England, made a steam-carriage for common roads, which he designed to carry passengers, and, which was probably the first ever constructed for that purpose only.

In December, 1833, about twenty steam-carriages and traction road-engines were running, or were in course of construction, in and near London.

In our own country the roughness of roads discouraged inventors, and, in Great Britain even, the successful introduction of road-locomotives, which seemed at one time almost an accomplished fact, finally met with so many obstacles that even Hancock, the most ingenious persistent, and successful constructor, gave up in despair. Hostile legislation procured by opposing interests, and possibly, also, the rapid progress of steam-locomotion on railroads, caused this result. In consequence of this interruption of experiment, almost nothing was done during the succeeding quarter of a century, and it is only within a few years that anything like a business success has been founded upon the construction of road-locomotives, although the scheme seems to have been at no time entirely given up.

J. Scott Russell, Boydell, and a few others in England, and Messrs. Roper, Dudgeon, Fawkes, Latta, and J. K. Fisher, in the United States, have all, at various times, labored in this direction. The last-named engineer designed his first steam-carriage in 1840.

Abroad, a few firms have succeeded, within a few years past, in making a business of considerable extent in constructing road-locomotives for hauling heavy loads, and in building steam road-rollers. The great impediments seem to be the roughness and bad construction of the ordinary highways, the damages arising from the taking fright of horses, the engineering difficulties of construction, and the limited power of the machine as it has usually been built.

103. FOREIGN TRIALS OF ROAD-ENGINES.—The capabilities of the road-locomotive are readily determined by experiment, and the following are the results of several series of trials made by the writer and others:

A trial of the machines of the British makers, Aveling and Porter, was made by Mon. H. Tresca, Sous Directeur du Conservatoire Imperial des Arts et Metiers, Paris, and a member of the International Jury. The report was submitted to the Directeur-general, Morin, January 15, 1868.*

The results may be summarized as follows:

1. The co-efficient of traction was determined to be about 0.25 on a good road with easy grades.
2. The consumption of coal was found to be 4.4 pounds per horse-power per hour.
3. The consumption of water was determined to be 132.2 gallons an hour with "ten-horse" engine.
4. The "co-efficient of adherence" or of friction between the wheels and the soil was 0.3.
5. A rate of motion of seven miles an hour produced no special difficulty in managing either the locomotive or its load.

This engine was of large size, having a steam-cylinder of 11 inches diameter, and a stroke of piston 14 inches. The crank-shaft was geared to the driving-wheels in such a manner as to make 20.33 or 14.25 revolutions, at pleasure, for each revolution of the drivers. The driving-wheels were 6½ feet in diameter, and the weight of the machine, exclusive of fuel and water in its tanks, was 14½ tons. Including fuel and water, its weight was 17½ tons. The load drawn on a level road was 79 tons, 19 hundredweights, 1 quarter, (77,597 kilograms,) including the weight of the machine itself.

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* Proces-verbal des Experiences faites sur une machine de traction; Conservatoire des Arts et Metiers; Paris, 1868.

This weight was distributed as follows:

	Per centum of totals.
Weight of engine	21.8
Weight of wagons	25.9
Weight of paying-load	52.3
	100

In an addenda to the report of M. Tresca, it is stated that M. Lalouette had set the engine at work transporting heavy material, and with the following results:

It transported a total weight of 2,500,000 kilograms a distance of 4 kilometers, drawing, on each trip, 25,000 kilograms of paying load, and making four trips per day. Five hundred kilograms of coal were consumed in eight journeys.

At about this same time M. Servel, Ingenieur-en-Chef de la Compagnie Générale des Messageries à Vapeur, conducted a series of experiments with a similar machine upon paved and upon macadamized roads, during what he described as the most trying of winter weather. Under such conditions, M. Servel reports the following distribution of weights by percentum:

Weight of locomotives	41.4
Weight of wagons	18.2
Weight of paying-loads	40.4
	100

The average total weight of three loaded wagons, which was the usual load, was 22,575 kilograms, or very nearly 22 tons. The experiment was made in 1867–'68 of applying these engines to the towage of boats on the French canals. The results seem to have been very encouraging. M. Géraldi reported that an eight-horse engine towed, on the canal between Caen and Oyestreham, a fleet, having an aggregate measure of 800 tons, at the rate of three miles an hour, and that the speed had been pushed up to six miles an hour.

M. Carfort reported to M. Huet that a six-horse engine, doing similar work on the Dunkerque and Saint Omer Canal, had towed 800 tons, and was regularly towing 500 to 700 tons, at an expense not exceeding 40 per centum of the cost of horse-power. In the year 1871 a number of traction-engines were exhibited before the Royal Agricultural Society of England, at their show at Wolverhampton, and the judges appointed by the society made a series of exceedingly interesting and instructive tests.*

The judges stated that, on a road in good order, wheels fitted with India-rubber tires, as patented by Thompson, have an advantage over iron rigid wheels in traction-force, but that the cost of such wheels—50 per cent. of the cost of the locomotive—forms a most serious obstacle to their adoption; still, they say that they "are not prepared to express a decided opinion upon that subject." On farm-roads and in fields the India-rubber tires "signally failed." Plain iron wheels, with "paddles" attached, succeeded where the former failed. A ten-horse locomotive entered by Messrs. Aveling & Porter received the first prize at the termination of these trials; two competing systems of rubber tires—those of Thompson and of Adams—were each awarded a silver medal; a six-horse-power road-locomotive, by Aveling & Porter, and an eight-horse-power road-engine, by Burrell, were very highly commended.

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* Journal of the Royal Agricultural Society of England, vol. vii. London. J. Murray, 1871.

The prize-engine had a cylinder of 10 inches diameter and a stroke of piston of 12 inches, a fire-grate area of 6½ square feet, an area of heating-surface of 204.4 feet, driving-wheels 6 feet in diameter and 18 inches breadth of face. These wheels made one revolution to seventeen of the crank-shaft. The total weight of the engine was 12 tons, of which 8¾ were on the driving-wheels. The coal used, on special trial, amounted to 3.2 pounds per indicated horse-power per hour, and the evaporation of water was 7.62 pounds per pound of coal consumed, the average temperature of feed being 175° Fahrenheit. The load drawn up the maximum grade of 264 feet to the mile on Tottenham Hill, which is 1,900 feet from top to bottom, was 26 tons, or, including weight of engine, 38 tons, giving a co-efficient of traction of 0.35. On a country-road, sixteen miles long, it drew 15 tons at an average rate of speed of three and a half miles per hour, using 2.85 pounds of coal and 1.94 gallons of water per ton of useful load per mile. On farm-soil, soaked with recent rains, the load drawn was 9 tons, and speed something less than an average of two miles per hour, using 13.6 pounds of coal per ton of paying load per mile. This engine was fitted with smooth-tired driving-wheels.

104. TRIAL OF ROAD-LOCOMOTIVES BY THE AUTHOR.—The writer made a public trial of these engines and a steam road-roller by the same builders (Aveling & Porter) in October, 1872, at South Orange, N. J., which was attended by the commissioners of public roads for the neighboring county, and by many members of the engineering profession from New York and other cities. Two road-steamers, or traction-engines, and a steam road-roller were brought out for exhibition and trial.

No. 1 was a new road-locomotive (Fig. 53) built by Messrs. Aveling & Porter; it had previously done no real work. A sketch of this machine is here given. It was of precisely the same size and pattern of one of those exhibited at Vienna, and above referred to. The following description will apply to both:

Principal dimensions:

Weight of engine complete, 5 tons 4 cwt., pounds	11,648
Steam cylinder, diameter in inches	7¾
Stroke of piston, inches	10
Revolution of crank to one of driving-wheels	17
Driving-wheels, diameter in inches	60
Driving-wheels, breadth of tire in inches	10

Driving-wheels, weight, pounds, each	450
Boiler, length over all, feet	8
Boiler, diameter of shell, inches	30
Boiler, thickness of shell, inches	$\frac{7}{16}$
Boiler, fire-box sheets, outside, thickness in inches	½
Load on driving-wheels, 4 tons 10 cwt., pounds	10, 080

The boiler was of the ordinary locomotive type, and the engine was mounted upon it, as is usual with portable engines.

The driving-pinion on the crank-shaft was made capable of being slipped out of gear, thus allowing the engine to be kept in motion when the locomotive was at rest, either to pump water into the boiler, or to drive as a "portable engine" by a belt which could be carried on the pulley, 4½ feet in diameter and 5 inches face, which was fitted to act as a fly-wheel. When used as a "portable engine," regulation was effected by means of a fly-ball governor conveniently attached. The cylinder was steam-jacketed in accordance with the most advanced practice here and abroad. The crank-shaft, and other wrought-iron parts subjected to heavy strains, were made of Lowmoor iron, and were strong and plainly finished. The gearing was of malleableized cast-iron, and all bearings from crank-shaft to driving-wheels, on each side, were carried by a single sheet of half-inch plate, which also formed the sides of the fire-box exterior. This simple device united all parts peculiarly exposed to injury by jarring, with such firmness as would seem to give perfect security against such injury even on rough roads. The engine valve-gear consisted of the standard arrangement of three-ported valve and Stephenson link, with the reversing lever, as used on locomotives. The feed-pump was driven by an eccentric keyed on the crank-shaft. The connection between the gearing and the driving-wheels was effected by one of the neatest and most ingenious devices known to engineers. This arrangement is called by builders of cotton machinery a "jack-in-the-box" gear, and the "differential" gear. As constructed, one wheel turns freely on the driving-axle, while the other driving-wheel is keyed fast. A bevel-gear is bolted on the hub of the wheel, and a similar gear is keyed to the driving-axle. Between these revolves a spur-gear, which is driven by the engine, and which carries two small bevel-pinions, the latter engaging both bevel-wheels, their axles being in the plane of revolution of the large gear. Resistances being equal on both wheels, if the spur-gear be turned it will carry with it both driving-wheels at the same time with equal angular velocities, the effort exerted by the engine being equal to both wheels at all times. If the engine be turning a corner, however, the greater resistance on the inside wheel retards that, while the outer wheel necessarily moves more rapidly over its longer path, and, while the engine still exerts the same force on both wheels, the work done is distributed unequally between them through the then revolving bevel-pinions, without loss, and without either wheel being necessarily slipped or disengaged. Should one wheel, however,

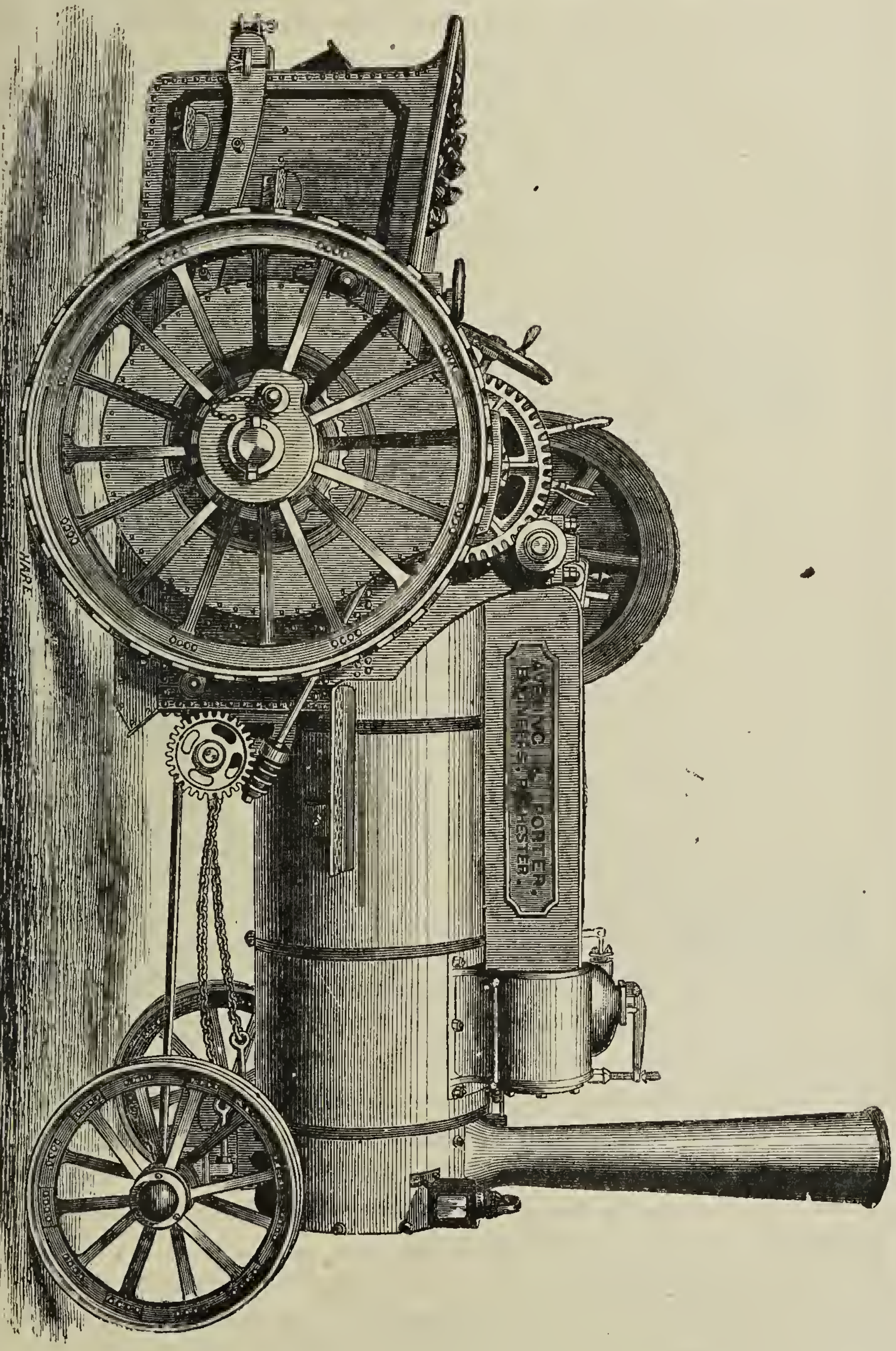
AVELING & PORTER.
ENGINEERS. ROCHESTER.
HARE

Fig. 53.—Aveling and Porter's road-locomotive.

strike into a soft spot, as a patch of muddy soil, and finding so little resistance as to turn freely, leaving the opposite wheel at rest on firmer soil and thus checking the motion of the locomotive, a heavy bolt, which is furnished with each machine ready fitted to its place, is inserted and keys the loose wheel to the shaft. Both wheels must thus turn together until, the locomotive being extracted, the bolt is withdrawn. Such an occurrence is seldom likely to take place.

The driving-wheels were wrought-iron, strong but light in their construction, and were fitted with strips of iron, thickest at the middle of their lengths, which were laid diagonally across the face of the wheels, with separating spaces of about two inches between them. The angle was such that one end of one strip would come to a bearing on the ground just as the opposite end of the preceding strip was leaving it.

The builders claim that this method of obtaining tractive-power in the wheel gives the engine a pulling-power, on good ground, equal to 0.45 of the insistent weight. On extremely hard and smooth roads, bolts are inserted in the wheel-rim, whose heads give better holding-power than even these iron strips, and on very soft ground the same bolts are used to secure to the rim of the wheel pieces of angle-iron, called by the builders "paddles," which take a good hold on the more unstable kinds of soil. The weight of this locomotive rested principally upon the driving-wheels. About 15 per centum was left upon the forward axle, to insure good steering power. The total weight on the drivers was somewhat increased, when pulling a load, by the inclination of the line of traction downward from the pulling-bolt to the point of attachment to the load.

The forward axle is fitted with wheels of 42 inches diameter and 8 inches face; it swings about a king-bolt, which is secured above in a bracket secured to the under-side of the boiler smoke-box, and is steadied by a strong rod, connecting its lower end with the forward end of the fire-box. Chains led from each end of the axle to a shaft carried on the forward end of the fire-box, around which they wound in such a manner that turning this shaft would swing the axle. A hand steering-wheel, conveniently arranged near the throttle and reversing handles, turned this shaft, being connected with it by means of a worm-shaft and pinion. A tank at the rear of the locomotive carried coal and water in its compartments, and afforded a standing-place for the engine-driver, from which he could readily reach the various handles and gauges. Draught was secured by means of the exhaust.

The boiler and steam-cylinder were both well protected against losses of heat by coverings of felt and lagging. No springs were used on the engine exhibited, as, being intended for heavy work at slow velocities, their advantages would not justify the expense and complication attending their use. A strap-brake was fixed on the driving-axle for the purpose of controlling the engine on heavy grades.

Road-locomotive No. 2 (Fig. 54) was of the same size and of similar

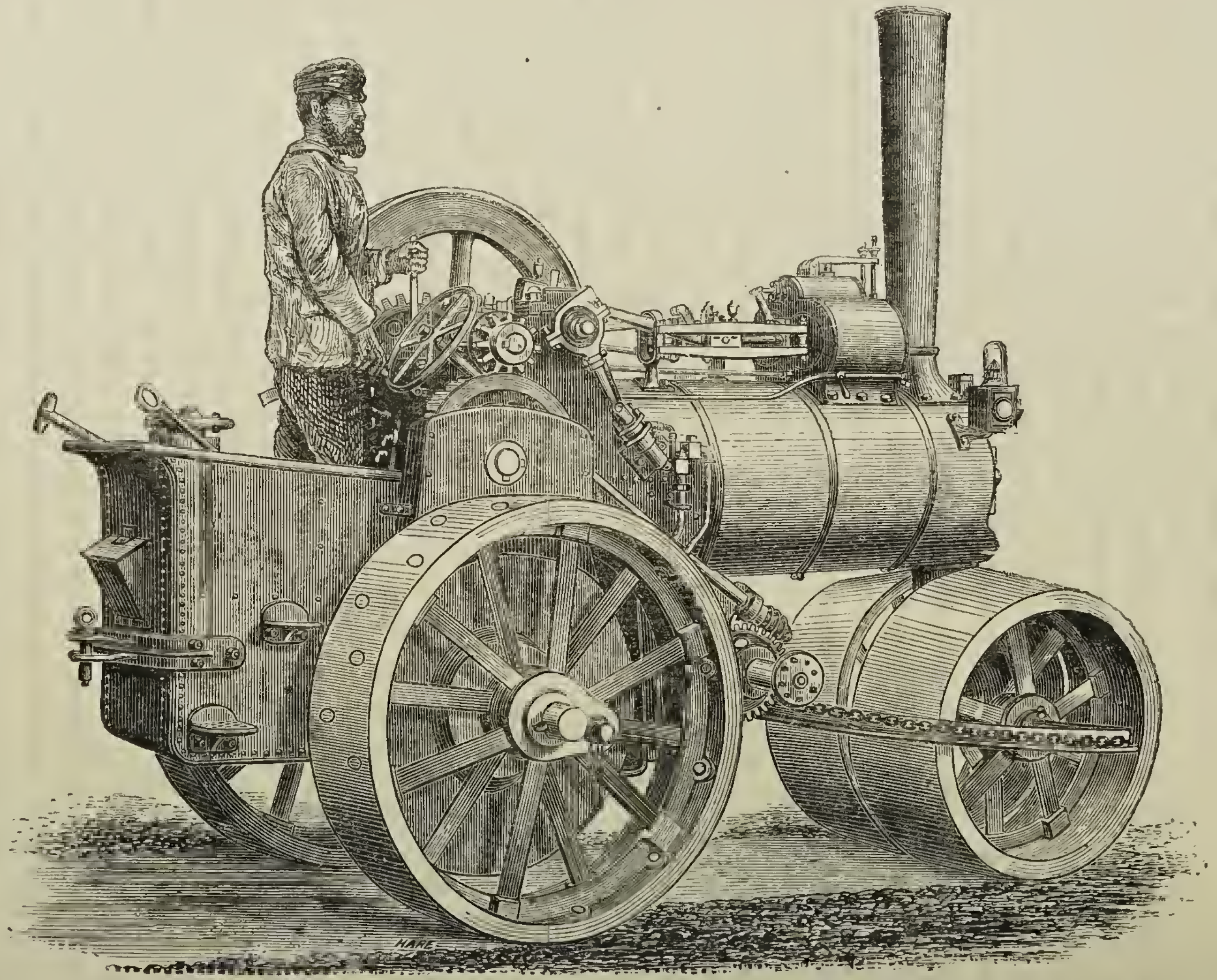

Fig. 54.—Aveling and Porter's steam road-roller.

make to No.1. It had been two years in use, or longer, as a steam road-roller. To convert it into a road-roller, its ordinary driving-wheels had been removed, and in their place were fitted a pair of cast-iron wheels of similar diameter, but of 20 inches breadth of face, and weighing 3,800 pounds each. Their faces were left smooth, as hauling power was not desired; and as it was intended that they should leave the surface of the road as smooth and as firmly compacted as possible. In these driving-wheels the engine carried an excess of weight of 6,700 pounds as compared with No. 1. In statements of work done, this excess should be entered as a part of the paying-load where No. 2 is employed as a traction-engine. The great weight of these wheels was important in preventing the liability of slipping, which is a consequence of their smooth surface, and should bring up the equivalent co-efficient of adherence, in terms of the original weight of the engine, to about 0.42, or nearly equal to that of No. 1 with its regular traction-wheels. As during the trial no slip was in any case observable, this difference would not in any way affect the results.

The road-bed was macadamized, and was remarkably smooth, hard, and compact.

Such remarkably fine roads are, unfortunately, too seldom seen in this country, although not infrequently met with in Great Britain and on the continent of Europe. The fact is due partly, no doubt, to the infrequency of occurrence of such excellent material for metalling, but it principally arises from the circumstance that very few boards of road commissioners are sufficiently interested in their work, and, at the same time, sufficiently energetic and far-sighted to indulge in what often seems extravagant expenditure, but what is really one of the most important among the means available for economizing greatly the cost of local and suburban transportation.

From the results obtained at this trial were made the following:

105. DEDUCTIONS.*—(1.) A traction-engine may be so constructed as to be capable of being easily and rapidly manoeuverd on the common road and in the midst of any ordinary obstructions.

(2.) Such an engine may be placed in the hands of the average mechanic, or even of an intelligent youth of sixteen,† with confidence that he will quickly acquire, under instruction, the requisite knowledge and skill in its preservation and management.

(3.) An engine weighing rather more than five tons may be turned continuously in a circle of 18 feet radius without difficulty, and without slipping either driving-wheel, even on rough ground, and may be turned in a road-way of a width but slightly greater than the length of the locomotive by proper manoeuvring.

(4.) A road-locomotive weighing 5 tons 4 cwt., has been constructed, which is capable of drawing, on a good road, more than 23,000 pounds up the almost unexampled grade of 533 feet to the mile at the rate of four miles an hour.

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* Communicated by the writer to the Journal of the Franklin Institute, 1873.

† The manufacturers state that one of their most skilful drivers at Wolverhampton was a boy of fourteen.

(5.) Such a locomotive may be made, under similar conditions, to draw a load of more than 63,000 pounds up a hill rising 225 feet to the mile, at the rate of two miles per hour, doing the work of more than twenty horses.

(6.) The action of the traction-engine upon the road is beneficial, even when exerting its maximum power, while, with horses, the injury to the road-bed is very noticeable.

(7.) The co-efficient of traction is, with such heavily laden and roughly made wagons as were used at South Orange and under the circumstances noted, not far from *four per centum* on a well-made macadamized road.

(8.) The amount of fuel, of good quality, used may be reckoned at less than 500 pounds per day, where the engine is a considerable portion of the time heavily loaded, and, during the remaining time, running light. It may be considered, without probability of serious error, that, during the trials at South Orange, engine No. 2 performed pretty nearly an average day's work.

106. A number of interesting problems may be solved by reference to the facts just stated. A comparison of the efficiency of the road steam-traction engine with that of horse-power, in drawing heavy loads, is especially important, and we will now make such a comparison, basing it upon the most reliable data at hand.

Traction-force.—Engine No. 2 developed a tractive force equal to that of twenty horses. The actual tractive force may be determined as follows: The co-efficient of traction was, as has been shown, not far from 0 0427, which is also very nearly the maximum figure given by General Morin, as determined by his experiments with "dray-carts" and "*chariot-porte-corps d'artillerie*," upon metalled roads and upon roads paved with sandstone.* This co-efficient is large, partly in consequence of the very slight breadth of the wheel-tires and the small diameter of the wheels of the wagons used, and partly because the wagon-bodies were not mounted on springs. To be absolutely certain that no error is committed by overestimation in the following calculation, this co-efficient will be taken at 0.03.

The actual traction-force required to overcome the rolling resistance was, then, $63,400 \times 0.03 = 1,902$ pounds. The force required to overcome that component of the force of gravity which directly resisted the motion of the load, in this case, where the road lay at an angle with the horizontal whose tangent was 0.0427, was $W \sin T = 2,700$ pounds; the total resistance was, therefore, 4,602 pounds.

Including the weight of the traction-engine itself, these figures become 2,251 and 3,002 pounds, giving a total of 5,253 pounds direct resistance, and a co-efficient of adherence of $5,253 \div 18,348 = 0.28$, which slightly exceeds that found on earlier trials of smooth wheels.

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* Morin's Mechanics. New York, D. Appleton & Co., 1860, p. 348.

Experiments made by Capt. Robert Merry, at the Jackson Iron Mine, Negaunee, Mich., and the observations and experiments of the writer, indicate the maximum direct tractive force of a good horse to be about 250 pounds. This corroborates the estimate already made, making the tractive power of this engine equal to that of twenty horses.

Deducing from the above the weight which could be drawn on an equally excellent but level road, by this locomotive, the co-efficient of traction being the same, we find it equal to $\frac{5,253}{0.03} = 175,000$ pounds, or very nearly 80 gross tons, and, excluding the weight of the locomotive, (163,452,) 75 tons. With the machine, as with the animal, it would not be expected that, in regular work on ordinary roads, more than one-half of the maximum power would be exacted,* although, with such a reserve, the machine possesses a decided advantage over the animal.

107. *Working time.*—The working time of a horse is usually considered to be eight hours per day for dray-horses, and less for carriage-horses. The dray-horse, which is kept in harness eight hours per day, is usually standing unworked a considerable proportion of this time, while his load is being handled, and also during one-half, usually, of the remaining time his vehicle is drawn unloaded. The horses of the Third-avenue street-railroad in New York City are worked less than six hours per day, and given one day in seven as a day of rest. This is about equal to the working time of horses and cattle crossing our western plains with moderate loads.

The steam-engine requires no such careful limitation of working time. It can work twenty-four hours uninterruptedly as readily as a single hour. Ten hours a day would be, in most cases, made the daily working-time of a road-locomotive, the period being determined by the proper length of the working-day of the driver, rather than by the capabilities of the machine.

The working time of the traction-engine may therefore be stated to be, ordinarily, 20 per cent. greater than that of the dray-horse, and to be capable of indefinite extension when required. The loss of working time by the horse through illness, at the farriery, &c., and that lost by the locomotive in the repair-shop, are proper subjects for comparison; but it is difficult to determine them in the absence of reliable data. We may estimate these losses as equally affecting the two motors, with a probability that the correction of any error in such estimate may make a change favorable to the locomotive.

108. *First cost.*—Comparing the first cost and running expenses of steam and of horse power, we may work from tolerably well-established data. The list-price of the Aveling & Porter road-locomotive experimented with at South Orange was, delivered in New York, about $4,000.

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* *Vide* "Steam-engines and Prime Movers," Rankine, chap. 3, p. 85.

The average cost of horses purchased by the Third-avenue Railroad in New York City was $157.50, and it would require more than twenty such horses to pull the load of the traction-engine, while an addition of 25 per cent. must be made for the greater length of the working-day of the locomotive. Twenty-five such horses would have a first cost of $3,937.50, to which must be added the large item of cost of harness.

The first cost of steam and of horse power is, therefore, nearly equal, the difference being in favor of steam, leaving, also, on the side of the engine the immense advantage arising from its ability to work longer hours when required, and indefinitely. The interests on these first costs also nearly balance each other.

109. *Running expenses.*—The running expenses of the locomotive are for attendance, fuel, oil, and repairs, and for depreciation in value with use; those of horse-power are for attendance, food, stabling, sickness, and depreciation with age.

The cost of attendance upon the one engine and the twenty-five horses may be taken at $939 and $3,130, respectively, assuming each driver of the latter to be able to manage a six-horse team. The engine-driver received $3 per day and the other men $2.50, and there are 313 working days in the year.

The cost of fuel, oil, and incidentals, excluding repairs of the engine and its depreciation, may be averaged at $900 per year in the vicinity of New York. This is somewhat higher than the cost of similar items on railroad-locomotives in New York State.*

The cost of repairs and depreciation had been so small at South Orange that it could not be estimated, but for the life of the engine it will be likely to average something less than 15 per cent. of the first cost, or, in this case, $600 per annum. This we arrive at by an examination of railroad-locomotive expenses,† as officially reported.

The total annual expense, therefore, of the traction-engine referred to may be reckoned at $2,439 as a maximum figure, including cost of attendance. A similar estimate will give for the annual expense of keeping one horse, very exactly $300, excluding attendance. In the year 1870, 10,315 horses in the State of New York cost for stabling, feeding, repairs to harness, and shoes, &c., according to the official statement, $3,182,838.24, or $308.56 each animal. From this is to be deducted about $8 per head for receipts from sales of horses, leaving for annual expenses, say, $300 per horse. The expense account, excluding attendance, would be, for twenty-five horses, $7,000 against $1,500 for a similar amount of steam-power, and, *including attendance,* $10,500 as against $2,439.

Referring once more to the expense-account of the Third-avenue Railroad, we find it working more economically than the average as above given. This company employs an immense number of horses, buys its supplies in large quantities, taking advantage of the market, and is able to do much better than could any individual or smaller capitalists. The following data were kindly furnished by Mr. Charles S. Arthur:

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* State Engineer's Reports.

† This is about the figure on good railroads in the United States; on British roads the range is from 10 to 25 per cent., averaging very exactly 15 per cent.

Average cost (first) of horses, per head	$157 50
Average price obtained when sold, three and one-half years later	65 00
Cost of stabling, general expenses, and incidentals	180 00
Total annual expenses, including depreciation	206 43
Add to the above the cost of harness, (not stated,) say	3 00

The total annual cost of horse-power, for comparison, 25 × $209.43 = $5,235.75, to which we add $3,130 for drivers, and we make a total cost per year of $8,365.75, to be compared with $2,439, the total annual expense of the road-locomotive, capable of doing an equal amount of work.

The expense-account when doing heavy work on the common road, under the described conditions, by steam-power is, therefore, less than 25 per centum of the average cost of horse-power, as deduced from the total expense of such power in New York State, while, if we take for comparison the lowest estimate that we can find data for in our whole country, we still find the cost of steam-power to be but 29 per centum of the expense of horses. We may state the fact in another way: A steam traction-engine, capable of doing the work of twenty-five horses, may be worked at as little expense as a team of six or eight horses.

110. One of the most important of the prerequisites to ultimate success in the substitution of steam for animal power on the highway is, that our roads shall be well made. As the greatest care and judgment are exercised, and an immense outlay of capital is considered justifiable, in securing easy grades and a smooth track on our railroad routes, we may readily believe that similar precaution and outlay will be found advisable in adapting the common road to the road-locomotive. It is undeniably the fact that, even when relying upon horse-power, so far, less attention has been paid to the improvement of our roads than true economy would dictate. With steam-power, the gain by careful grading and excellence of construction of the road-bed becomes still more important. The animal mechanism is less affected in its power of drawing heavy loads than is the machine. With the horse, a bad road impedes transportation principally by resisting the movement of the load rather than of the animal, while with the traction-engine the motor is as seriously retarded as the train which follows it, and frequently much more, on soft ground. Steam, therefore, cannot be expected to attain its full measure of success on rough and ill-made roads; but where highways are as intelligently engineered and as thoroughly well built as those on which the trials at South Orange were made, or where nature has relieved the engineer and the road-builder of the ex-

pensive work of grading, as throughout a very large extent of the western and southern portion of our country, we may expect to see the road-locomotive rapidly introduced.

111. The earliest and most perfect success of the traction-engine, and its probable successor, the steam-carriage, may be expected to occur in these districts. Its great economical advantage over animal power, as exhibited above, its freedom from liability to become disabled by epizootic diseases, its reliability under all circumstances, and the many other advantages which are possessed by the machine, are already securing its rapid introduction, despite the difficulties arising from popular prejudice and unfamiliarity, from hostile municipal laws and other existing obstacles.

We are learning that this motor, when it can be used at all, is comparatively inexpensive; that our roads are improved by it, and that the ancient idea of its conflicting with the interests of owners and workers of horses is only a superstition.

The principal inconvenience that may be anticipated will probably arise from the carelessness or avarice of proprietors, which may sometimes cause them to appoint ignorant and inefficient engine-drivers, giving them charge of what are always excellent servants, but terrible masters. Nevertheless, as the transportation of passengers on railroads is found to be attended with less liability to loss of life or injury of person than their carriage by stage-coach, it will be found, very probably, that the general use of steam in transporting freight on common roads may be attended with less risks to life or property than to-day attends the use of horse-power.

CHAPTER V.

PORTABLE ENGINES; STEAM FIRE-ENGINES.

SOURCES OF ECONOMY IN PORTABLE ENGINES; READING IRON-WORKS ENGINES; MARSHALL, SONS & CO.; CLAYTON & SHUTTLEWORTH; AVELING & PORTER; ROBEY & CO.; E. R. & F. TURNER; RANSOME, SIMS & HEAD; THE STRAW-BURNER; OTHER ENGINES; IMPORTANCE OF THE PORTABLE-ENGINE TRADE; ROTARY STEAM FIRE-ENGINES; THE ENGINE OF THE SILSBY MANUFACTURING CO.; ADVANTAGES; BRITISH AND AMERICAN STEAM FIRE-ENGINES; MERITS OF AMERICAN STEAM FIRE ENGINES; HISTORICAL SKETCH OF THEIR INTRODUCTION.

PORTABLE STEAM-ENGINES built by British builders have for many years excelled all others, with, perhaps, the exception of an American builder, Mr. J. C. Hoadley, of Lawrence, Mass., and the later work of the best English builders has given economical results that have surprised engineers. The sharp competition of leading firms at the annual shows of the Royal Agricultural Society has recently brought out most gratifying evidences of skill in management as well as of excellence of design and construction. Some of these little portable engines have exhibited an economical efficiency superior to that of the largest marine engines of any but the compound type, and even closely competing with that form. The causes of this remarkable—almost incredible—economy are readily learned by an inspection of these engines as exhibited at Vienna, and by observation of the method of managing them at the test trial. The engines are usually very carefully designed. The cylinders are nicely proportioned to their work, and their pistons travel at high speed. Their valve-gear consists usually of a plain slide-valve, supplemented by a separate expansion-slide, driven by an independent eccentric, and capable of considerable variation in point of cut-off. This form of expansion-gear is very effective—almost as much so as a drop cut-off—at the usual grade of expansion, which is not far from four times. The governor is usually attached to a throttle-valve in the steam-pipe, an arrangement which is not the best possible under variable loads, but which produces no serious loss of efficiency when the engine is driven, as at these competitive trials, under the very uniform load of a strap-brake and at very nearly the maximum capacity of the machine. The most successful engines have had steam-jacketed cylinders, an essential to maximum economy with high steam and a considerable expansion. The boilers are strongly made, and are, as are also all other heated surfaces, carefully clothed with non-conducting material, and well lagged over all. The details are carefully proportioned; the rods and frames are strong and well secured together; the bearings have large rubbing surfaces;

the connecting-rods are long and easy working, and every part is capable of doing its work without straining and with the least friction.

In handling the engines at the competitive trial, most experienced and skilful drivers are selected. The difference between the performances of the same engine in different hands has been found to amount to from 10 to 15 per cent., even where the competitors were both considered exceptionally skilful men. In manipulating the engine, the fires are attended to with the utmost care; coal is thrown upon them at regular and frequent intervals, and a uniform depth of fuel and a perfectly clean fire are secured with remarkable success. The sides and corners of the fire are looked after with especial care. The fire-doors are kept open the least possible time; not a square inch of grate-surface is left unutilized, and every piece of coal gives out its maximum of calorific power and in precisely the place where it is needed. Feed-water is supplied as nearly as possible continuously and with the utmost regularity. In some cases, the engine-driver stands by his engine constantly, feeding the fire with coal in handfuls and supplying the water to the heater by hand by means of a cup. Heaters are invariably used in such cases. The exhaust is contracted no more than is absolutely necessary for draught. The brake is watched carefully lest irregularity of lubrication should cause oscillation of speed with the changing resistance. The load is made the maximum which the engine is designed to drive with economy. Thus all conditions are made as favorable as possible to economy, and they are preserved as invariable as the utmost care on the part of the attendant can make them.

These trials are usually of only three or five hours duration, and thus terminate before it becomes necessary to clean fires.

The following are results obtained at the trial of engines which took place in July, 1870, at the Oxford agricultural fair:

Makers' name and residence.	Cylinders.		Stroke.	Horse-power.		Point of cut-off.	Revolutions per minute.	Pounds coal per horse-power per hour.
	Number.	Diameter.		Nominal.	Dynamometric.			
		In.	*In.*					
Clayton, Shuttlewood & Co., Lincoln	1	7	12	4	4. 42	......	121. 65	3. 73
Brown & May, Devizes	1	7 3-16	12	4	4. 19	11-48	125. 65	4. 44
Reading Iron-Works Company, Reading		5 3-4	14	4	4. 16	.....	145. 7	4. 65

These were horizontal engines, attached to locomotive boilers.

At a similar exhibition held at Bury, in 1867, considerably better results even than these were reported as below from engines of similar size and styles. Subsequent trials have given similarly excellent results.

Makers' name and residence.	Cylinders.			Horse-power.		Point of cut-off.	Revolutions per minute.	Pounds coal per horse-power per hour.
	Number.	Diameter.	Stroke.	Nominal.	Dynamometric.			
		In.	*In.*					
Clayton, Shuttleworth & Co., Lincoln	1	10	20	10	11.00	3-10	71. 5	4. 13
Reading Iron-Works Company, Reading	1	8 5-8	20	10	10.43	1-4	109. 4	4. 22

With all these engines steam-jackets were used, the feed-water was highly and uniformly heated by exhaust steam, the coal was selected, finely broken, and thrown on the fire with the greatest care, the velocity of the engines, the steam-pressure, and the amount of feed-water were very carefully regulated, and all bearings were run quite loose; the engine-drivers were usually expert "jockeys."

113. Yet, even under such conditions as have been described, the results obtained seem very extraordinary. The Reading Iron-Works, Marshall, Sons & Co., and Messrs. Clayton & Shuttleworth, all of whom exhibited at Vienna, obtained most excellent economy, and other firms did quite good work.

The first-named firm, in 1872, were reported to the Royal Agricultural Society at Cardiff to have obtained the following results on such a trial: The engine, with a cylinder of 8½ inches diameter and 14 inches stroke of piston, had 205 square feet of heating surface, of which about 40 were in the fire-box. Its grate had an area of 7¼ square feet, which was reduced to 2½ square feet during the trial. The tubes were 2¾ inches diameter and 39 in number.

With steam-pressure at 80 pounds per square inch and at about 150 revolutions per minute, the engine developed 20½ indicated and 16⅞ dynamometrical horse-power, and consumed less than 2½ pounds of picked coal per indicated horse-power per hour, the boiler evaporating 10 pounds of water per pound of coal. The amount of water used was 24 pounds per indicated horse-power per hour, and burned at the rate of over 20 pounds per square foot of grate per hour. The engine was of the type above described, but the governor was attached to a right and left hand screwed stem, moving the cut-off blocks on the back of the main valve. With a powerful and yet delicate governor, this is an excellent arrangement. The governor has been connected to the cut-off valve of the portable engine by Mr. Hoadley also. The engine exhibited at Vienna was similar to that which gave this exceedingly creditable result on trial.

114. Messrs. MARSHALL, SONS & CO., of Gainsborough, exhibited portable engines of the class called in Great Britain "semi-fixed," in which the engine and boiler were mounted together, but were not carried on wheels as are the really portable machines. In design and in

construction and finish these engines were among the best shown in the British section. The Hartnell & Guthrie shifting-eccentric was used, and this by its adjustability to different extent of throw, gave the same flexibility of valve-adjustment attained by the better-known "Dodd motion."

115. Messrs. CLAYTON & SHUTTLEWORTH exhibited a large collection of engines and boilers. This firm, which was founded in 1848, is said to have constructed between 12,000 and 13,000 engines. They have had a large branch establishment at Vienna for many years, and now have a large share of the continental trade in this class of machinery. The principal characteristics of these engines were quite similar to those of other builders of the better class of engines, and they were equally admirable in design, construction, and finish.

116. Messrs. AVELING & PORTER were also exhibitors of most commendable engines. ROBEY & Co. exhibited engines remarkable for their fine finish. Some were fitted with Richardson's governor, mounted on the crank-shaft, and acting upon the cut-off valve through an eccentric with a modified Dodd motion. The device was said to work very satisfactorily.

Messrs. E. R. & F. TURNER, of Ipswich, exhibited an engine which, although not as highly finished as some others, was of excellent form and proportions, and was reported to be exceedingly economical. It had the Hartnell & Guthrie governor attached to a valve patented by the builders. The main valve is a piston-valve 6 inches in diameter, for a cylinder of 12 inches diameter, and resembles, in some respects, the Davis valve, used in the engine exhibited by the New York Safety Steam Power Company. The engine was reported, at Cardiff, in 1872, to regulate remarkably well, and to perform very economically, notwithstanding the use of but one valve instead of attaching an independent cutoff valve.

117. Messrs. RANSOME, SIMS & HEAD were large exhibitors of a considerable variety of machinery, including several steam-engines of the class here considered. One of these engines was adapted to burning straw and other vegetable refuse. It was exhibited at a public trial, and its performance was so satisfactory as to attract the attention of both engineers and agriculturists. This machine was especially designed to meet a demand which promises to become an important one, and particularly in many portions of continental Europe, where the raising of grain forms the principal business of the farming population. The plan is said to have originated with a Russian engineer, Mr. Schemioth, who was assisted in the development of the invention by Mr. Head, the junior partner of the firm.

As arranged at Vienna, the straw was driven into the furnace by feeding-rollers, moved by a belt from the crank-shaft, and hangs suspended above the grates a short time, while the flame rising from the half-consumed fuel on the bars, seizes it, and its combustion is partially accomplished before it falls. The essential feature of success seemed to be the free supply of air thus secured for every portion of the combustible mass. The grates are liable to become choked by a mineral, silicious deposit—the ash formed—and a raking apparatus is provided, by means of which its removal is effected at intervals. To avoid danger from fire, the ash-pan is closed at the nearer end, and the ashes are kept moistened by a small stream of water from the feed-pump. The consumption of fuel is reported to be three and a half to four times the weight of coal usually required, and one sheaf of straw suffices to thresh twelve or fifteen sheaves of wheat. The combustion was very perfect and rapid.

The boiler is given a greater area of heating surface than is given for equal power when wood or coal is the fuel.

The engine exhibited at Vienna was rated at ten-horse power. Its cylinder was of 9 inches diameter, and the stroke of piston 1 foot; speed of piston 280 feet per minute, or 140 revolutions; the heating surface measured 210 square feet. It was said to develop 20 indicated horse-power.

The best portable engine of standard design exhibited by Ransome, Sims & Head was rated at 12 horse-power. It was 8.4 inches in diameter of cylinder, one-foot stroke; it was regulated for 140 revolutions per minute, and had 210 square feet of heating surface. Steam was carried at 90 pounds pressure per square inch.

The cylinders were steam-jacketed on both sides and ends; the inner "working-barrel" being made separately and forced into the main casting. Separate slide-expansion valves were used, worked by independent eccentrics, adjustable in position to give a range of expansion from one and one-half to five times. A feed-water heater, with an independent feed-pump, furnished water to the boiler nearly at the boiling point. The engine was stated to be capable of working up to 35-horse-power, with a consumption of 3½ to 3¾ pounds of coal per horse-power per hour. The point of cut-off was adjustable by the Brown arrangement of governor. It does very good work, and the indicator diagrams show a very fair distribution of steam.

These engines were beautifully finished, were well made, and evidently well prepared to do good work. In this, as in several other exhibits, the crank-shafts were *bent* to shape—an excellent practice. A *buckle* on the governor-belt to permit taking up slack showed careful attention to details on the part of the builders.

118. Messrs. JOHN FOWLER & Co. exhibited their agricultural machinery in great variety, and deserve credit for the excellence of design and workmanship and for their success in the field. The writer found their apparatus at work on the estate of Baron von Horsky, doing excellent work—plowing. The portable engine driving the plows was a strong, well-proportioned and well-built engine, and seemed capable of long service without serious expense for repairs.

119. There were several other portable engines exhibited at Vienna by British builders, some of which were hardly less creditable to their makers than those mentioned above, while, in one case at least, they were crude in design, rough in workmanship, and without finish.

As a rule, the British builders were without rivals in the exhibition in this branch of work. The American Engine Company, J. C. Hoadley, and possibly one other firm in the United States are rivaling the best of them, but the portable engine has not received the attention that it deserves in this country, and there remains ample room for other good builders in our markets. Although manufacturers may take a just pride in building large steam-engines on the most approved plans, with elaborate expansion-gear and with condensing apparatus, the more extended market is that for small engines, and for portable engines particularly. The market for small, simple, well-proportioned, and carefully-made engines will always be large, and it may always be relied upon as far steadier and safer than that for larger machinery. Our builders cannot do better than to follow, and, if possible, to excel, the British makers in this direction.

The French section contained three or four portable engines. That of M. HERMANN LACHAPELLE was well made, of very good design, and, in the absence of the magnificent show of British engines, would have been considered worthy of special mention. The other French engines were quite unworthy even of criticism.

The other continental builders of portable engines were, evidently, usually following in the track, although far in the rear, of the English makers, and their engines require no mention, except in the case of Sigl, of Vienna, whose exhibit was very creditable.

120. STEAM FIRE-ENGINES.—The Silsby Manufacturing Company, of Seneca Falls, New York, exhibited a well-built and finely-finished steam fire-engine, with rotary engine and pump, (Fig. 55.) The superiority of a rotary motion for a steam-engine is apparently so evident that it is not strange that many attempts have been made to overcome the practical difficulties to which it is subject. One of these difficulties, and the principal one, has been the packing of the part which performs the office of the piston in the straight cylinder. Robert Stephenson expressed the opinion, a few years ago, that a rotary engine would never be made to work profitably on account of this difficulty of packing. The most palpable of the advantages of the rotary engine are the reduction in the size of the engine, claimed to result from the great velocity of the piston, avoidance of great accidental strains, especially noticed in propelling ships, and a great saving of the power which is asserted to be expended in the reciprocating engine in overcoming the inertia while changing the direction of the motions. These advantages adapt the rotary engine, in an especial manner, to the driving of a locomotive or steam fire-engine. This application has been made, and all difficulties are claimed to have

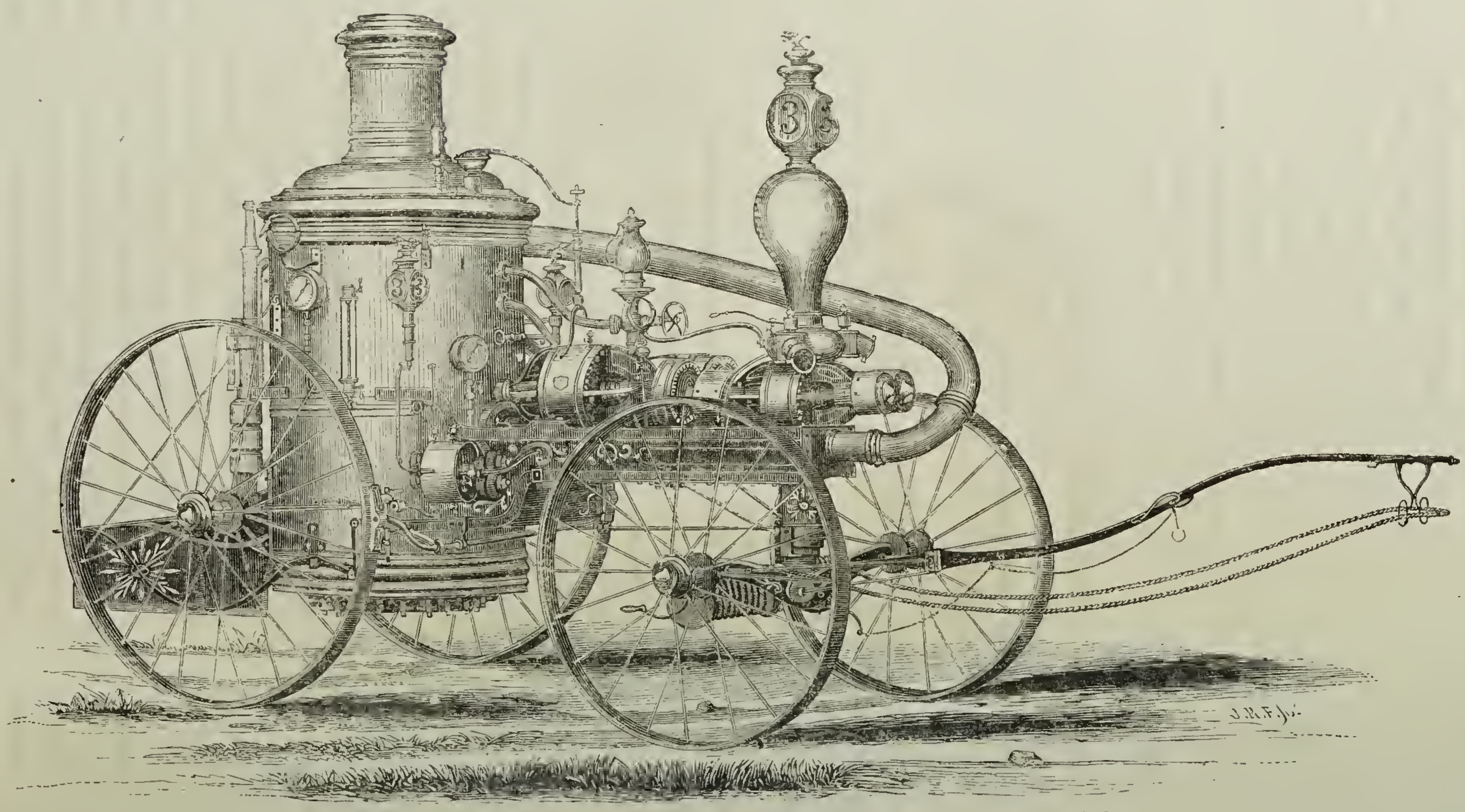

FIG. 55.—Steam fire-engine—Silsby Manufacturing Company, U. S.

been surmounted. The packing, after three years' trial, it is stated, has been found perfectly tight.

121. In these rotary engines and pumps (Fig. 56) all eccentrics and sliding cams, which are frequently used in rotary engines, and which are so objectionable on account of their great friction, are avoided. Corrugated pistons, or irregular cams, C D, are adopted, forming chambers within the cases. In the engine the steam enters at A, at the bottom of the case, and presses the cams apart. The friction in this engine is claimed to be very small, as the only packing used is in the ends of the long metal cogs, which are ground to fit the case and are kept out by the momentum of the cams, assisted by a slight spring back of the packing-pieces. The friction on the pump is claimed to be less than in the engine. This is the reason given in support of the claim that the rotary engine forces water to a given distance with from one-fourth to one third the steam-pressure necessary to drive all reciprocating engines. The smaller amount of power necessary to do the work, the less strain and consequent wear and tear upon the whole machine, are said to make it more durable and reliable. The pump being chambered, its liability to injury by the use of dirty or gritty water is lessened, and it is stated that it will last for years, pumping gritty water that would soon cut out a piston-pump.

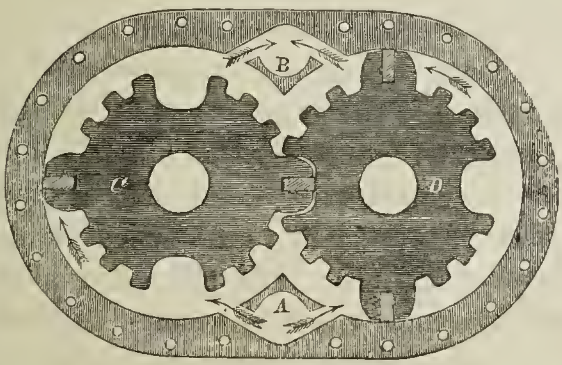

FIG. 56.

122. The advantages of the rotary engine are: The ease of its operation and the absence of the crank-motion which is found in all reciprocating machines. The high speed at which all engines must be driven in steam fire-engines makes it necessary that the reciprocating engine should be very strong and heavy to bear the jerking and straining to which they are subjected in passing the centers. The rotary engine has not that difficulty to contend against. The machine stands perfectly still when in operation. There is no necessity for blocking the wheels or jacking the boiler off the springs. There is no vibration of the hose, and the pressure being steady and uniform, it does not strain the hose, as happens from the blows of a piston. Hose that will not bear the pressure of the piston of the reciprocating-pump to force water 200 feet, it is said by these builders, will stand the uniform pressure of the rotary engine when

throwing the stream 230 feet. Hose used on a rotary engine will wear longer than that used on a piston-engine, as it lies perfectly still while the machinery is in operation, and consequently does not wear out by friction upon the ground or pavement. The pipe of a rotary engine is held more easily than that of a piston-engine. This is of great advantage to the fireman in ascending ladders to the upper portion of a building. Another advantage is claimed to be the low pressure of steam with which the rotary engine can be driven, it being seldom necessary to use over 40 pounds to do effective fire-duty. The suction-hose is, in this engine, always attached to the pump, and has only to be lifted out of the hooks on the side of the machine and dropped into the water or attached to a hydrant, and the leading hose being laid and attached, the machine is ready for operation. There are no valves in either engine or pump, and the whole arrangement is so simple that any careful man may be intrusted with the engine. They require two men, the engineer and fireman, while in operation. The engine has a feed-pump for supplying the boiler while the machine is in operation, and an independent donkey-pump. It also has an arrangement for supplying the boiler from the main pump, so as to insure supplying water, under any and all circumstances and for any length of time. The "Washington 8," of Mobile, a third-size engine, is reported by these exhibitors to have worked over 136 hours at a fire, merely stopping to change the location of the hose. Another advantage claimed for this machine is that the boiler is so constructed that impure or salt water can be used without causing it to foam or prime. This, they state, has been tested at Providence, R. I., one of the old and seven of the new styles being in use in that city, all of which have been used with salt water in their boilers while working at fires in the lower part of the city, where fresh water could not be obtained without difficulty. The boiler can easily be repaired, and every part is accessible without taking the machine apart. The advantage of the steam fire-engine over the hand-engine for the extinguishment of fires has now been long recognized. The experience of all cities and villages that have adopted a steam fire-department indicate they are more effective, less troublesome to manage, and also less expensive to maintain, than the hand-engine department.

123. Messrs. SHAND & MASON and Messrs. MEREWETHER, of London, exhibited heavy, but well-built steam fire-engines. It is unfortunate that several American firms, noted for their excellence of product in this class of machinery, had not exhibited their fire-engines.

124. AMERICAN STEAM FIRE-ENGINES.—There were no steam fire-engines exhibited by the best known American builders of engines with reciprocating engines and pumps, such as are in general use in the United States, and have become standard in general plan and arrangement of details. These are probably the best illustrations which have ever been produced of extreme lightness, combined with strength of parts and working power, which have ever been produced in any branch

of mechanical engineering. By using a small boiler crowded with heating-surface, very carefully proportioned and arranged, and with small water-spaces; by adopting steel for running-gear and working parts wherever possible; by working at high piston-speed and with high steam-pressure; by selecting fuel with extreme care; by all these expedients the steam fire-engine has been brought, in this country, to a state of efficiency far superior to anything seen in Europe. Steam is raised with wonderful promptness, even from cold water, and water is thrown from the nozzle at the end of long lines of hose to great distances.

But this combination of lightness with power is only attained at the expense of a certain regularity of action which can only be secured by greater water and steam capacity in the boiler. The small quantity of water contained within the boiler makes it necessary to give constant attention to the feed, and the tendency, almost invariably observed, to serious foaming and priming not only compels unintermitted care while running, but even introduces an element of danger which is not to be despised, even though the machine be in charge of the most experienced and skilful attendants.

The limited steam-space in these boilers also introduces another objectionable feature by producing such a tendency to variation of steam-pressure that even the most expert firing (stoking) cannot secure immunity from serious oscillations of steam-pressure. The skill with which these engines are usually handled is most remarkable, and it can only be the product of long practice and excessive care.

But even the greatest care, directed by the utmost skill, would not avail to prevent frequent explosions, were it not for the fact that it rarely, if ever, occurs that accidents to boilers occur from low water, unless the boiler is actually completely emptied of water. In driving them at fires, they frequently foam so violently that it is utterly impossible to obtain any clew to the amount of water present, and the attendant usually keeps his feed-pump on and allows the foaming to go on. As long as water is passing into the boiler it is very unlikely that any portion will become overheated and that accident will occur. Such management appears very reckless, and yet accident from such a cause is exceedingly rare, even if any such accident has been known.

Where it is uncertain whether there is sufficient water in the foaming boiler, a prudent engineer is careful to keep his feed-pump on and his engine running until he can find the water-level. If he finds himself actually caught with an overheated boiler, he promptly deadens his fire without stirring it, avoiding any other change of condition. The best way to proceed is probably to cover the fire with damp ashes or sand.

125. HISTORICAL SKETCH.—The steam fire-engine is peculiarly an American production; although previously attempted, their permanently successful introduction has only occurred within the last fifteen years.

As early as 1830, Braithwaite, of London, Great Britain, built an engine with steam and pump cylinders of 7 and 6½ inches diameter, respectively, with 16 inches stroke of piston. This machine weighed two and a half tons, and is said to have thrown 150 gallons of water per minute to a height of between 80 and 100 feet. It was ready for work in about twenty minutes after lighting the fire. Braithwaite afterward supplied a more powerful engine to the King of Prussia, in 1832.

The first attempt made in the United States to construct a steam fire-engine was probably that of Hodge, who built one in New York in 1841. It was a strong and very effective machine, but was far too heavy for rapid transportation.

The late J. K. Fisher, who throughout his life persistently urged the use of steam-carriages and traction-engines, designing and building several, also planned a steam fire-engine. Two were built from his design by the Novelty Works, New York, about 1860, for Messrs. Lee & Larned. They were "self-propellers," and one of them, built for the city of Philadelphia, was sent across on the highway, driven by its own engines. The other was built for and used by the New York fire department, and did good service for several years. These engines were heavy, but very powerful, and were found to move at good speed under steam and to manœuvre well.

The Messrs. Latta, of Cincinnati, soon after succeeded in constructing comparatively light and very effective engines, and the fire department of that city was the first to adopt steam fire-engines definitely as their principal reliance. This change has now become general.

A self-propelling engine by the Amoskeag Company had the following dimensions: Weight, four tons; speed, eight miles per hour; steam-pressure, 75 pounds per square inch; height of stream from 1¼-inch nozzle, 225 feet; 1¾-inch nozzle, 150 feet; distance horizontally, 1¼-inch nozzle, 300 feet; 1¾-inch, 250 feet.

The Fire-Extinguisher, which has now become an essential article of furniture in so large a proportion of the houses of people in good circumstances in the United States, was not shown. This modern representative of the "Fire Cart," introduced by Captain Manby, in Great Britain, a half century ago, is a very important modern device, and should have been exhibited in all its variety of construction and mounting. One of the Babcock Manufacturing Company's carriages would have been very interesting to European visitors, and its lightness, power, and handiness would have surprised all.

CHAPTER VI.

STEAM-BOILERS AND ATTACHMENTS.

PITKIN BROTHERS' BOILER; THE GALLOWAY BOILER; TRIAL OF GALLOWAY BOILER; DATA AND RESULTS; HOWARD'S AND OTHER SECTIONAL BOILERS; HISTORICAL SKETCH OF SECTIONAL BOILERS; THEIR ADVANTAGES AND DISADVANTAGES; TEST OF THEIR ECONOMICAL PERFORMANCE; METHOD OF MAKING UP DATA; TABULAR EXHIBIT OF RESULTS; DETERMINATION OF PERCENTAGE OF PRIMING; FINAL RELATIVE STANDING; DESCRIPTION OF THE HOWARD BOILER; SPECIAL ADVANTAGES; THE SINCLAIR BOILER; ADAMSON'S BOILERS; THE BOILERS OF DAVEY & PAXMAN; THE BELLEVILLE BOILER; BOILERS OF MEYER, EHRHARDT, BERGMAN, PAUCKSCH & FREUND; SIGL'S BOILER AND LEH'S GRATE; BOLZANO, TEDESCO & CO.'S BOILERS; BOLZANO'S GRATE; BERRYMAN'S HEATER AND FEED-WATER REGULATOR; GREEN'S AND TWIBIL'S ECONOMIZERS; INJECTORS OF SELLERS, FRIEDMAN, AND KORTING; PHILOSOPHY AND HISTORY OF THE INJECTORS; PRINCIPLES OF STEAM-BOILER CONSTRUCTION.

126. The steam-boilers exhibited at Vienna were not remarkable for their number, their novelty of design, nor, generally, for exceptionally fine workmanship. One boiler only was exhibited in the United States section, by Pitkin Brothers & Co., of Hartford, Conn.* It was a tubular

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* The following extract from a letter from Mr. Pickering, engineer of the United States Department at the Vienna Exhibition, gives interesting information concerning the Pitkin boiler here alluded to. It was 54 inches in diameter, 16 feet long, with 59 tubes 3 inches in diameter and 15 feet long:

"Your boiler was subjected to the customary hydrostatic test, and it was declared by the officer in charge to be the only one of the entire collection at this Exposition which stood the cold-water test without leaking. And now the boiler has been in constant use nearly two and a half months, and has, to the surprise of every one, (including myself,) supplied our department with all the steam we need, and that with very easy firing and very poor coal. We are running daily four steam-engines: one 30, two 8, and one 3 horse-power; one 650-pound steam-hammer, one steam puddling-machine engine, of 5 horse-power, three steam-pumps, and other machinery, and supplied steam, when wanted, for the sand-blast exhibit of Tilghman, of Philadelphia. The main steam-pipe furnished by the Austrian General Commission is of very thin iron, 6 inches in diameter and 150 feet long. From this pipe all the steam is supplied, except through 48 feet of 1½-inch pipe continued from the end of the 6-inch pipe, making a total distance of this last engine from boiler 238 feet, as there are 40 feet of 3-inch pipe connecting boiler to the 6-inch main pipe. This steam piping is not covered, and consequently condenses much steam; so much, in fact, that it was necessary to place a straw-trap about the middle of the length of this pipe to relieve it of the water of condensation. The exhaust-pipes of these engines and pumps are so far from the boiler that it was found impracticable to use the exhaust steam for heating the feed-water; consequently, we feed cold water. I am now more than ever impressed with the economy and safety of this style of boiler, and our present and previous commissioners, as well as myself, desire to express our thanks for your liberality and promptness in furnishing, for use of the American department of this Exposition, so good a boiler, and one which is so true a sample of a style of boiler now so much in use in the United States.

"Very truly yours,

"T. R. PICKERING,

"*Engineer United States Department, Vienna Exposition.*"

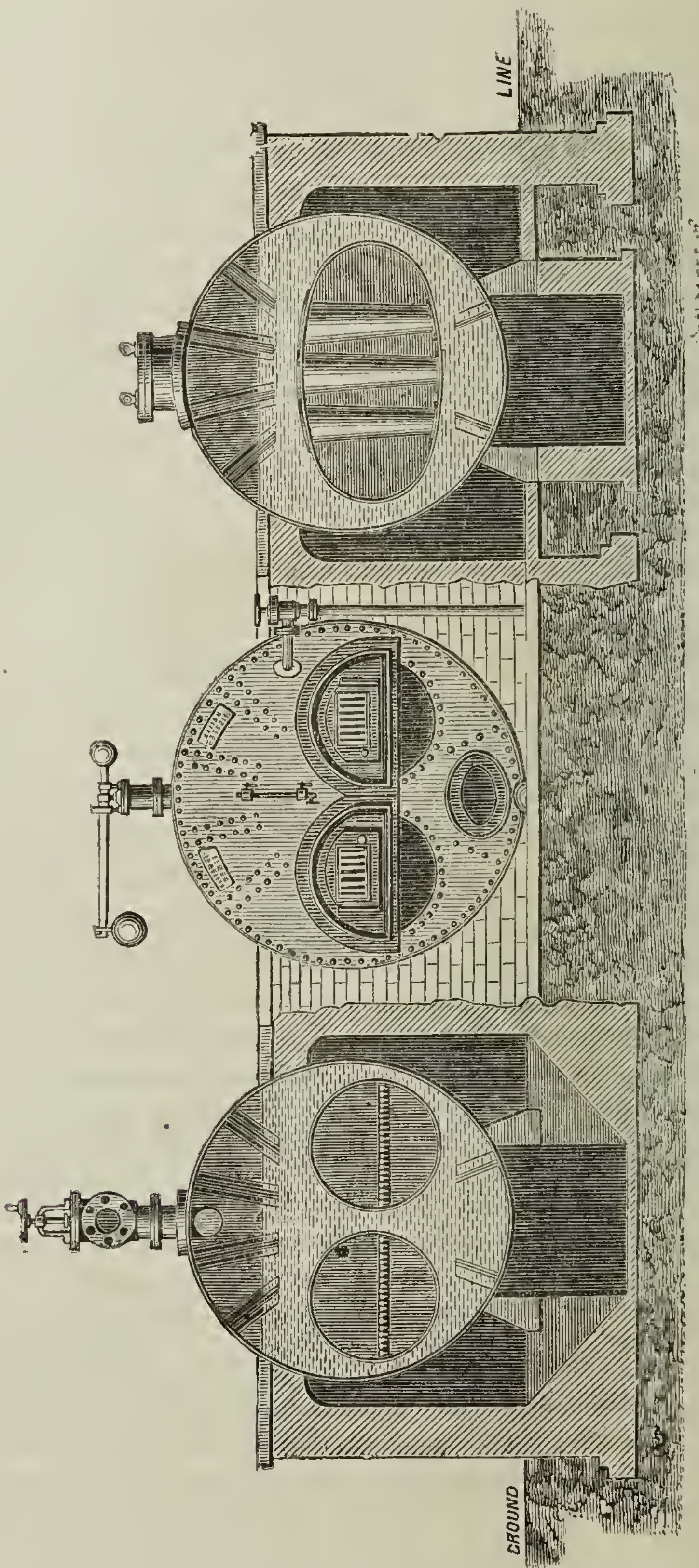

FIG. 57.—The Galloway steam-boiler—front elevation and section.

boiler of small size, of good proportion, and of excellent material and workmanship. The furnace was below the boiler, the gases passing back under the shell and returning through the tubes. The boiler did good work throughout the period of the Exhibition.

127. In the British section, the exhibit of Messrs. W. & J. GALLOWAY & SONS is interesting as illustrating the use of their conical tubes, (Fig. 58.) These are very largely used in Great Britain, but are seldom if ever seen in the United States. The Cornish boiler, to which they are usually applied, consists of a large cylindrical shell, 6 feet or more in diameter, containing one tube of about one-half as great dimensions, or sometimes two of one-third the diameter of the shell each. Such boilers have a very small ratio of heating to grate surface, and their large tubes are peculiarly liable to collapse.

To remove these objections, the Messrs. Galloway introduced stay-tubes (Figs. 58, 59, 60) into the flues, which tubes are conical in form, and are set in either a vertical or an inclined position, the larger end uppermost. The area of heating-surface is thus greatly increased, and, at the same time, the liability to collapse is reduced. It is stated that more than 100,000 of these tubes are in use. The same results are obtained by another device of Galloway, which is sometimes, as at Vienna, combined with that just described in the same boiler. Several sheets in the flue are worked in "pockets" which project into the flue-passage.

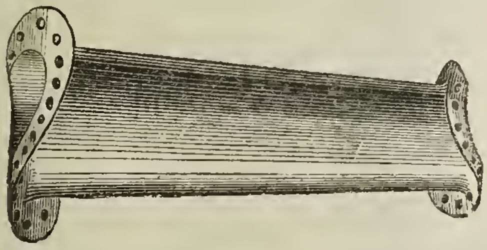

FIG. 58.

The Galloway boilers exhibited are shown in elevation, plan and sections, (Figs. 57, 59, and 60,) and had each two furnace-flues, of 34 inches diameter each, opening into one large elliptical flue 69 inches wide by 36 inches high, its inner axis vertical, which was stayed by 24 Galloway tubes, (Fig. 59,) and by six side-pockets, as seen in Fig. 60. The gases issued from the rear end of the boiler, and thence passed underneath it to the chimney. The shell was 24 feet long and 7 feet in diameter.

128. TRIAL OF A GALLOWAY BOILER.—The following report of a trial of a Galloway boiler at the mill of C. R. Collins, esq., at which were present the editor of "Engineering," C. R. Collins, esq., Byron Donkin, esq., engineer, London, and Chas. J. Galloway, Manchester, was handed the writer by the exhibitors.

The boiler was rated by the makers as a 55-horse-power boiler, was 26 feet long by 7 feet in diameter, and was made of $\frac{3}{8}$-inch plates, double-riveted at the longitudinal seams. The two front flues were each 2 feet 10 inches in diameter and 7 feet long; they were made of $\frac{3}{8}$-inch plates, with welded

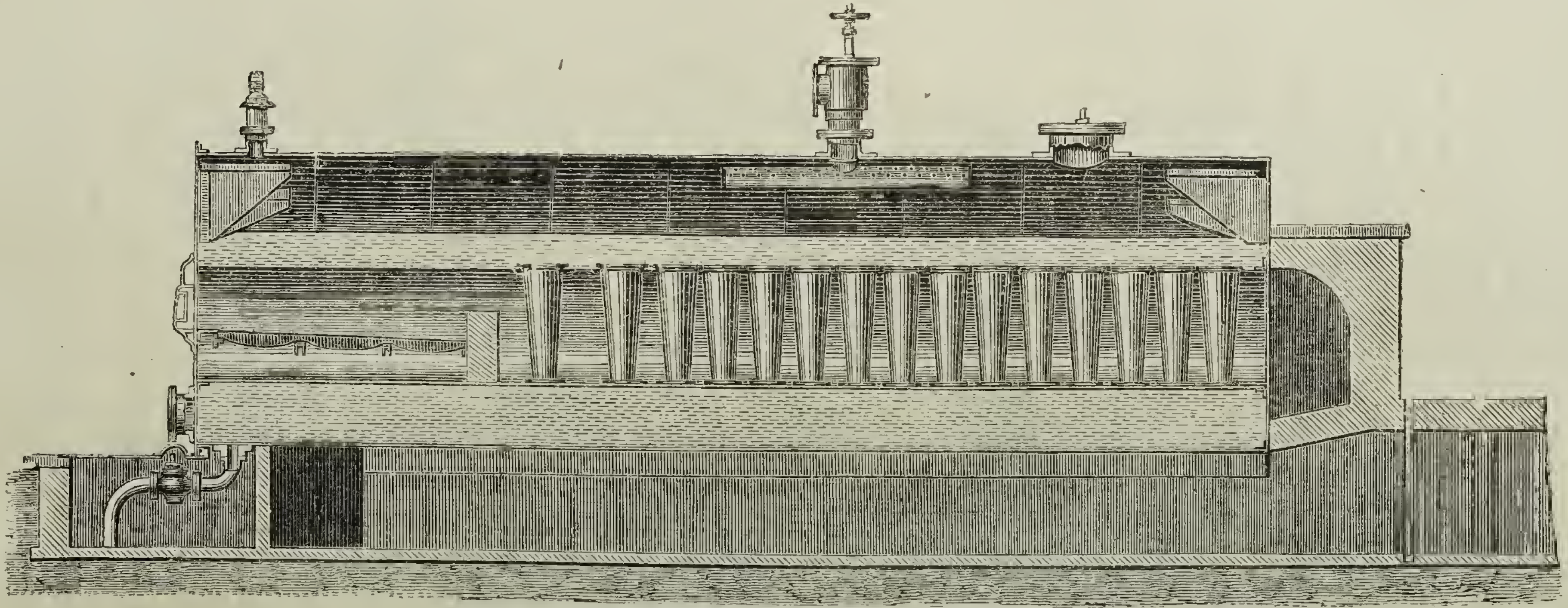

FIG. 59.—The Galloway steam-boiler—vertical section.

seams, and were strengthened by T-iron rings, while the back flue, which was of elliptical section, had a horizontal diameter of 5 feet 8 inches and a vertical diameter of 3 feet. This back flue was traversed by 27 Galloway tubes, each 10½ inches diameter inside at the top and 5½ inches at the bottom, while it was also made with a pair of side "pockets," these "pockets" causing the mixture of the gases coming from the two front flues. The fire-bars of each grate were in three 2-feet lengths, and the fire-grate area is 33 square feet. The hot gases, on escaping from the back flue, are led along the two sides of the boiler and then back under the bottom of the latter to the chimney.

The total heating-surface of the boilers was as follows:

	Square feet.
Fire-boxes	72
Over-flue	240
Twenty-seven cone-tubes and two pockets	144
Side-flues	220
Bottom-flue	72
Total	748

The boiler had been thoroughly cleaned out and the flues swept prior to the trial, and it had, in fact, only been lighted up about twenty-one hours when the trial commenced, so that the brickwork setting was scarcely thoroughly warmed through. This was slightly against it, as was also the fact that it was worked very much below its real power, so that the constant losses due to radiation, &c., went far to balance any advantage due to the slow combustion and the very moderate evaporation per square foot of heating-surface. The boiler was fed by a small donkey-pump, this pump being, during the experiment, supplied with steam from an adjacent boiler, so that its use should not affect the results obtained from the main engine. The boiler under trial was situated at the end of a range of boilers to which the steam-pipe was connected. To do away with any chance of leakage through the one connecting stop-valve, however, the adjacent boiler was kept at the same pressure as that under trial during the whole of the experiment, so that there should not be the slightest tendency to leak either way. The boiler was carefully lagged, as was also the steam-pipe which connected it with the engine.

The boiler was fed from a small cast-iron tank, situated by its side, and to which the donkey-pump already mentioned was attached. This tank was fitted with a gauge showing the water-level, and at the end of the experiment the water was brought to precisely the same level as that at which it stood at the commencement. The water used was filled into the tank by two cylindrical cans, each closed at the upper end, with the exception of a small opening, so that they could be accurately filled. The number of can-fulls of water used was noted by two observers, whose records were found to agree, and the cans themselves

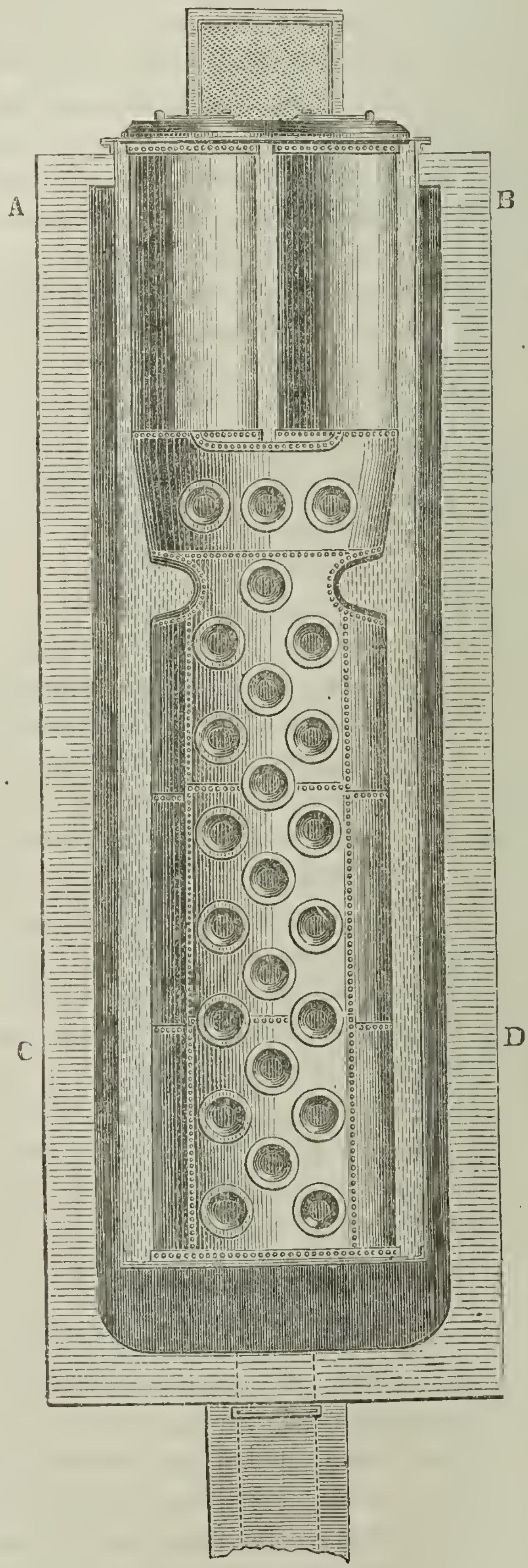

FIG. 60.—The Galloway steam-boiler—plan and section.

carefully weighed full and empty, and the weight of water used thus ascertained. The temperature of the feed-water was also taken at intervals of about 20 minutes.

Before the experiment commenced, all coals were cleared completely away from the front of the boiler, and into the space thus made the coals to be used on the trial were weighed, under the supervision of Mr. Collins. The coals used were Powell's Duffryn, and were of excellent quality. In commencing the experiment at 9.30 a. m., on a signal being given from the engine-house, the water-level in the boiler was marked on a scale fixed to the glass of the water-gauge, the pressure of steam was noted, and both fires were drawn at once, with the exception of about a shovel-full left in each furnace for re-lighting. About 12 pounds of wood were then thrown in, and the firing commenced with the weighed coal, the drawn fires being cleared away. When the fires were drawn, the steam stood at 50 pounds per square inch, in five minutes it had fallen to 49 pounds, but in fifteen minutes it had risen again to 49½ pounds, and in twenty-five minutes it was at 54 pounds. During the day it was kept almost constantly at 53 pounds, scarcely ever varying from this pressure more than a couple of pounds, and the mean of forty-nine observations, taken at intervals of twelve minutes, showed the pressure last mentioned to be the average throughout the experiment. At 6.45 p. m., when the experiment was approaching a close, the pressure was 51½ pounds, while at the end of the trial it was 49¾ pounds, or almost exactly the same as at the beginning, while the water-level was also precisely the same. On notice being given from the engine-house that the trial was completed, both fires were drawn, and the coal, cinders, &c., taken out and set on one side to cool, while at the same time the ash-pits were cleaned out.

129. When cool, the materials drawn from the fires were passed over a sieve with ¼-inch meshes, and the clinkers picked out by hand, and the weights were then found to be as follows:

	Cwt.	Qr.	Lbs.
Cinders	2	0	15
Siftings	0	0	26
Clinkers	0	0	10
Dirt from ash-pit	0	1	25
Total	2	3	20

The total amount of coal charged into the furnaces during the trial was 12 cwt., and the quantity consumed was thus 9 cwt. 0 qr. 18 lbs.= 1,016 lbs. plus its proper proportion of the dirt. Of the siftings, one-half was judged to be good fuel and the other half dirt, and the total quantity of dirt was thus 13 lbs. siftings+10 lbs. clinkers+53 lbs. from ash-pit= 76 lbs. in all, or almost exactly 5.66 per cent. Of this 76 lbs. of dirt, 12 lbs. (a quantity rather below the proper percentage) was taken as belonging to the 239 lbs. of cinders drawn from the fire, and the remainder, 64 lbs., was added to the fuel actually consumed, thus raising the latter to 1,080 lbs.

The quantity of water fed into the boiler during the trial was 11,691 lbs., and the evaporation, therefore, took place at the rate of $\frac{11691}{1080}=$ 10.82 lbs. of water per pound of coal. Considering that the mean temperature of the feed was $61\frac{3}{4}°$, this was a remarkably high evaporation, and affords good testimony as to the efficiency of the boiler.* We may add that the experiments made on the engine prove decisively that the quantity of water above mentioned was really evaporated, and that none of it passed away in priming.† This is an important point, and it is one of many in favor of the system of engine-testing adopted on the occasion of which we are speaking. It will be noted that during the trial the boiler was worked far below its real power, the rate of evaporation being but 1.56 pounds per square foot of total heating-surface per hour. There can be no doubt that this contributed to the economical results obtained; but at the same time, for reasons to which we have before referred, the advantage gained by this very slow rate of evaporation was not so great as might at first sight be supposed. In February, last year, the same boiler was tested with an evaporation of 28,087 pounds of water in ten hours, (a quantity nearly two and a half times as great as that evaporated during this trial,) and this weight was evaporated with a consumption of 2,919 pounds of coals, containing 2.8 per cent. of dirt, the evaporation being thus rated at 9,622 pounds per pound of coal. In this instance the temperature of the feed was 75°, and the general conditions and arrangements for ascertaining the results were

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* It may be convenient for comparison with data derived from other experiments to reduce the results above stated to the equivalent evaporation from a temperature of 212°, and under the ordinary atmospheric pressure. To do this we may employ the convenient and well-known formula of Professor Rankine to determine what he has termed the factor of evaporation. This formula is—

$$\text{Factor} \times \frac{0.3\ (T_1 - 212°) \times (212\ T_2)}{966}$$

in which T_1 = the temperature at which evaporation takes place, and T_2 = the initial temperature of the feed. In the case of experiments above recorded, T_1=310.2°, that being the temperature of steam at a pressure of 53 pounds above the atmosphere, while $T_2 = 61\frac{3}{4}°$. The factor was thus:

$$1 \times \frac{0.3(310.2 - 212) \times (212 - 61.75)}{966} = 1 \times \frac{179.71}{966} = 1.186$$

Multiplying now the evaporation obtained during the experiments by this factor, we get 10.82 × 1,186 = 12.83 pounds, as the equivalent evaporation which would have been obtained if the feed had been supplied at 212°, and the water boiled off under ordinary mean atmospheric pressure.

† Unfortunately, it remains uncertain how much of this was water actually evaporated and how much was "primed."

The remark, made above in regard to determining this by experiments upon the engine, can hardly be accepted as decisive on this point. See Art. 136 for the method adopted by the author in determining accurately the extent to which priming occurs.—R. H. T.

similar to those adopted at the more recent trial. For convenience of reference we give here, in a tabular form, a comparison of the principal data derived from this trial and from that of February, 1871.

	Trial February 8, 1871.	Trial October 11, 1871.
Quantity of coals burned per hour ...pounds..	291. 9	108
Quantity of coals burned per square foot of grate...do....	8. 85	3. 27
Quantity of coals burned per square foot of heating-surface...do ...	0. 39	0. 144
Quantity of water evaporated per hour from above temperature....do...	2, 808. 7	1, 169. 1
Quantity of water evaporated per pound of coal ...do....	9. 622	10. 82
Quantity of water evaporated from temperature of feed per square foot of heating-surface per hour...pounds..	3. 75	1. 56
Equivalent quantity of water which would have been evaporated from a temperature of 212°, and under atmospheric pressure for each pound of coal consumed, (by Professor Rankine's formula)...pounds..	11. 28	12. 83
Percentage of dirt and clinkers...per cent..	2. 8	5. 66
Temperature of feed ...degrees..	75	61. 75

RESULTS OF THE TRIAL OF A GALLOWAY BOILER, OCTOBER 11, 1871.

		Square feet.
Heating-surface,	fire-boxes	72
	oval flue	240
	27 cone-tubes and two pockets	144
	side flues	220
	bottom flues	72
Total		748
Fire-grate area		33

Results of trial.

Duration of trial, from 9.30 a. m. to 7.30 p. m		10 hours.
Mean pressure per square inch of steam in boiler-house, average of 49 observations made at intervals of about 12 minutes		53 pounds.
Initial temperature—mean of 28 observations		61. 75°
		Pounds.
Feed-water.	Quantity evaporated during 10 hours = 108 cans, weight of each can 108½ pounds	11, 691
	Quantity evaporated per hour	1, 169. 1
	Quantity evaporated per minute	19.48
	Quantity evaporated per indicated horse-power per hour	20.55
	Quantity evaporated per pound of coal consumed	10.82
Coal.	Description: Powell's Duffryn.	
	Quantity consumed during ten hours	1, 080
	Quantity consumed per square foot of fine-grate per hour	3.27
	Quantity consumed per indicated horse-power per hour	1.91
	Percentage	5.66 per cent.
Average temperature of outer boiler		57°
Average temperature in boiler		63°

From the above experiment it will be seen that the "Galloway" boiler evaporated 10.82 pounds of cold water per pound of Welsh coal. Had the temperature of the feed been raised to 212° (which is often exceeded where an economizer is used) and the water evaporated at atmospheric pressure, the result would have been 12.83 pounds of water per pound of coal, an evaporation which has perhaps never been exceeded by any other form of boiler.*

The boiler in this case was worked much under its ordinary power, as, with a condensing-engine, in good working order, it would drive 250 indicated horse-power with a pressure of 50 pounds or 60 pounds of steam.

130. Messrs. HOWARD, of Bedford, England, exhibited a boiler of a type which, in the United States, is largely known as the sectional boiler. In this class, of which there are many different kinds in the market, the water-space of the boiler is contained in a large number of small compartments, each of which is very strong, and the explosion of any one of which is not likely to produce that destruction of property and that great loss of life which so frequently follow the explosion of the more common kind of boiler.

131. HISTORICAL SKETCH OF SECTIONAL BOILERS.—The earliest boiler of this class was probably that of Col. John Stevens, of Hoboken, N. J., still preserved and now in the possession of the Stevens Institute of Technology. Dr. Alban forty years later attempted to bring this type into general use, and constructed a number of such boilers. Their introduction, like that of all radical changes in engineering, has been but slow, and it has been only recently that their manufacture has become an important branch of industry.

A committee of the American Institute, of which the writer was chairman, in 1871, examined several boilers of this and the ordinary type very carefully, and reported that they felt "confident that the introduction of this class of steam-boilers will do much toward the removal of the cause of that universal feeling of distrust which renders the presence of a steam-boiler so objectionable in every locality. The difficulties in thoroughly inspecting these boilers, in regulating their action, and other faults of the class are gradually being overcome, and the committee look forward with confidence to the time when their use will become general, to the exclusion of older and more dangerous forms of steam-boilers."

132. VALUE OF SECTIONAL BOILERS.—The economical performance of these boilers with a similar ratio of heating to grate surface should be equal to that of other kinds. In fact they are usually given a somewhat higher ratio, and their economy of fuel frequently exceeds that of the other types. Their principal defect is their small capacity for steam and water, which makes it extremely difficult to obtain steady steam-pressure.

Where they are employed, the feed and draught should be, if possible, controlled by automatic attachments, and the feed-water heated to the highest attainable temperature. At best, their satisfactory working depends, more than in other cases, on the skill of the fireman, and can only be secured by the exercise of both care and skill.

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* See preceding foot-note.—R. H. T.

133. ECONOMY OF SECTIONAL BOILERS.—The comparative economical efficiency of this class of boilers is well exhibited by the report of the committee above alluded to; and their report is the more interesting from the fact that it embodies the results of trials in which the actual evaporative powers of boilers were determined, evading the error which is usually produced where the water passing off with the steam, as in the last-described trial, is not measured and its weight deducted from the apparent weight of steam formed.

Results of a competitive trial of Sectional and other Steam-Boilers.

Boiler.	Square feet.		Ratio of heating-surface to grate-surface.	Total weights.					Ratio of water primed to water evaporated.	Mean temperatures.						
	Grate-surface.	Heating-surface.		Coal.	Combustible.	Feed.	Steam.	Primed water.		Injection.	Feed.	Water of condensation.	Discharge.	Steam.	Super heat.	Flues.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.	P.
A	27	876½	32. 5	3, 800	3, 185. 5	27, 896	27, 896	0.	0.	45°. 94	45°. 94	58°. 31	143°. 1	334°. 6	16°. 08	416°. 6
B	32¼	920	28. 5	5, 375	4, 527	39, 670	39, 670	0.	0.	45°. 5	45°. 5	63°. 48	154°. 76	330°. 63	13°. 23	345°. 87
C	23	600	26. 1	2, 800	2, 274	20, 428	19, 782. 94	645. 06	3. 26	45°. 65	45°. 65	54°. 38	120°. 83	321°. 06	0°.	503°. 76
D	37¾	913	24. 2	4, 400	3, 705	34, 000	31, 663. 35	2, 336. 65	6. 9	45°. 0	45°. 0	54°. 8	131°. 5	319°. 48	0°.	389°. 6
E	8½	440	51. 8	1, 232	1, 047. 5	10, 152. 5	9, 855. 6	296. 9	3.	44°. 4	44°. 4	49°. 49	106°. 14	323°. 75	0°.	221°. 67

Boiler.	Total British thermal units.	Total units per pound of combustible.	Apparent evaporation.				Actual evaporation.		Equivalent evaporation of water at 212° Fahr. and atmospheric pressure.	Square feet of heating-surface required to evaporate one cubic foot of water per hour.	Coal, lbs. per square foot, grate-surface per hour.	Efficiency; actual evaporation of fuel divided by theoretical.
			Per pound of coal.	Per pound of combustible.	Per square foot of grate-surface per hour.	Per square foot of heating-surface per hour.	Per pound of coal.	Per pound of combustible.				
	Q.	R.	S.	T.	U.	V.	W.	X.	Y.	Z.	Z 1.	Z 2.
A	32, 751, 834. 34	10, 281. 53	7. 34	8. 76	86. 09	2. 65	7. 34	8. 76	10. 64	23. 59	11. 73	0. 709
B	46, 387, 827. 1	10, 246. 92	7. 38	8. 76	102. 51	3. 59	7. 38	8. 76	10. 60	17. 41	13. 88	0. 707
C	23, 066, 685. 39	10, 143. 66	7. 26	8. 95	73. 70	2. 83	7. 07	8. 70	10. 49	22. 74	10. 13	0. 699
D	37, 228, 739. 072	10, 048. 24	7. 68	9. 12	75. 06	3. 10	7. 20	8. 55	10. 40	21. 63	9. 71	0. 693
E	11, 485, 777. 35	10, 964. 94	8. 24	9. 69	99. 53	1. 92	8. 00	9. 41	11. 34	33. 48	12. 10	0. 756

The boilers tested were A and B, true "sectional boilers;" C, a semi-sectional, and D and E, boilers which were tubular boilers of more nearly the ordinary type. All of the steam formed was condensed in a surface-condenser of 1,100 square feet area of refrigerating-surface. The coal used was anthracite, of excellent quality, containing 91 per cent. carbon, and capable of affording, if perfectly utilized, 13,197 British thermal units of heat per pound of coal, and of evaporating 13.65 pounds of water at the boiling-point.

The preceding table, exhibiting the results of the trials, which were of twelve hours' duration each, affords valuable information not readily obtainable:

135. In calculating the results from the record of the logs, the committee first determined the amount of heat carried away by the condensing water by deducting the temperature at which it entered from that at which it passed off. To this quantity is added the heat which was carried away by evaporation from the surface of the tank, as determined by placing a cup of water in the tank at the top of the condenser at such height that the level of the water inside and outside the cup were the same, noting the difference of temperatures of the water in the cup and at the overflow, and the loss by evaporation from the cup. The amount of evaporation from the surface of the water in the cup and in the condenser, which latter was exposed to the air, was considered as approximately proportional to the tension of vapor due their temperatures, and was so taken in the estimate. The excess of heat in the water of condensation over that in the feed-water also evidently came from the fuel, and this quantity was also added to those already mentioned.

The total quantities were, in thermal units, as follows:

A	34,072,058.09
B	48,241,833.60
C	24,004,601.14
D	38,737,217.57
E	11,951,002.10

These quantities, being divided by the weight of combustible used in each boiler during the test, will give a measure of their relative economical efficiency; and, divided by the number of square feet of heating-surface, will indicate their relative capacity for making steam. But as it was the intention of the committee to endeavor to establish a practically-correct measure that should serve as a standard of comparison in subsequent trials, it was advisable to correct these amounts by ascertaining how and where errors had entered, and introducing the proper correction. There were two sources of error that are considered to have affected the result as above obtained. The tank being of wood, a considerable quantity of water entering it, leaked out again at the bottom, without increase of temperature, instead of passing through the tank and carrying away the heat, as it is assumed to have done in the above calculation. The meters also registered rather more water than actually passed through them, and this excess assists in making the above figures too high. The sum of these errors the committee estimated at 4 per cent. of the total quantity of heat carried away by the condensing water. The other two quantities were considered very nearly correct.

Making these deductions, we have the following as the total heat, in British thermal units, which was thrown into the condenser by each boiler:

A	32,751,835.34
B	46,387,827.10
C	23,066,685.39
D	37,228,739.07
E	11,485,777.35

That the figures thus obtained are very accurate is shown by calculating the heat transferred to the condenser by A and B, (both of which superheated their steam,) by basing the calculation on the temperature of the steam in the boiler, as given by the thermometer, the results thus obtained being 32,723,681.76 and 46,483,322.5, respectively.

Dividing these totals by the pounds of combustible consumed by each boiler, we get as the quantity of heat per pound, and as a measure of the relative economic efficiency:

A	10,281.53
B	10,246.92
C	10,143.66
D	10,048.24
E	10,964.94

Determining the weight, in pounds, of water evaporated per square foot of heating-surface per hour, we get as a measure of the steaming capacity:

A	2.65
B	3.59
C	2.83
D	3.10
E	1.92

The quantity of heat per pound of combustible, as above determined, being divided by the latent heat of steam at 212° Fahrenheit, (966°.6,) gives as the equivalent evaporation of water at the pressure of the atmosphere, and with the feed at a temperature of 212° Fahrenheit:

A	10.64
B	10.60
C	10.49
D	10.40
E	11.34

For general purposes, this is the most useful method of comparison for economy.

The above figures afford a means of comparison of the boilers, irrespective of the condition (wet or dry) of the steam furnished by them. All other things being equal, however, the committee considered that boiler to excel which furnished the driest steam; provided that the superheating, if any, did not exceed about 100°.

In this trial the superheating was as follows:

A	16°. 08
B	13. 23
C	0.
D	0.
E	0.

136. As the boilers C D E did not superheat, it became an interesting and important problem to determine the quantity of water carried over by each with the steam. This we are able, by the method adopted, to determine with great facility and accuracy.

Each pound of saturated steam transferred to the condensing water the quantity of heat which had been required to raise it from the temperature of the water of condensation to that due to the pressure at which it left the boiler, *plus* the heat required to evaporate it at that temperature. Each pound of water gives up only the quantity of heat required to raise it from the temperature of the water of condensation to that of the steam, with which it is mingled. The total amount of heat is made up of two quantities, therefore, and a very simple algebraic equation may be constructed, which shall express the conditions of the problem:

Let—

H = heat units transferred per pound of steam.
h = heat units transferred per pound of water.
U = total quantity of heat transferred to condenser.
W = total weight of steam and water, or of feed-water.
x = total weight of steam.
$\mathrm{W}-x$ = total weight of water primed.

Then—

$$\mathrm{H}x + h\,(\mathrm{W}-x) = \mathrm{U};\ \text{or}\ x = \frac{\frac{\mathrm{U}}{h} \quad \mathrm{W}}{\frac{\mathrm{H}}{h}-1}$$

Substituting the proper values in this equation, we determine the absolute weights and percentages of steam and water delivered by the several boilers, as follows:

	Weight of steam.	Weight of water.	Percentage of water primed to water evaporated.
A	27, 896.	0.	0.
B	39, 670.	0.	0.
C	19, 782. 94	645. 06	3. 26
D	31, 663. 35	2, 336. 65	6. 9
E	9, 855. 6	296. 9	3.

And the amount of water, in pounds, actually evaporated per pound of combustible—

A	8.76
B	8.76
C	8.70
D	8.55
E	9.41

137. Comparing the above results, the committee were enabled to state the following order of capacity and of economy, in the boilers exhibited, and their relative percentage of useful effect, as compared with the economical value of a steam-boiler that should utilize all of the heat contained in the fuel:

	Steaming capacity.	Economy of fuel.	Percentage of economical effect.
A	No. 4	No. 2	0.709
B	1	3	0.707
C	3	4	0.699
D	2	5	0.693
E	5	1	0.756

The results obtained, as above, and other very useful determinations derived from this extremely interesting trial, were given in the table, as a valuable standard set of data with which to compare the results of other trials, and as a useful aid in judging of the accuracy of statements made by boiler-venders in the endeavor to effect sales by presenting extravagant claims of economy in fuel.

As some authorities consider the evaporation of one cubic foot per hour to be the equivalent of one horse-power, column Z was introduced into the above table to give the area of heating-surface required in each boiler, per horse-power, on this basis. A good modern steam-engine ought not to require more than one-half the specified amount.

This class of boilers is thus seen to be very economical. The boiler E should be expected to excel, in consequence of its immense area of heating-surface.

138. THE HOWARD BOILER.—The boiler of Messrs. Howard, as exhibited at Vienna, (Fig. 61,) was of the same class as boiler A above, and with similar proportion should give equally good results. It consisted of 20 tubes, of 9 feet length and 9 inches diameter each,-a size about twice as great as those of the boilers just referred to. They were placed in a position slightly inclined from the horizontal, very much as in the boiler known in the United States as the Root boiler. The steam-drum was formed by a larger cylinder placed above the tubes and set in a line at right angles to that of the smaller tubes. A similar but smaller cylinder at the lower part of the back end of the boiler received the feed-water and distributed it to the several sets of tubes. The tubes were lapwelded. Their front ends were plugged with iron screw-caps, and the rear ends, which were slightly raised, were screwed into a set of ver-

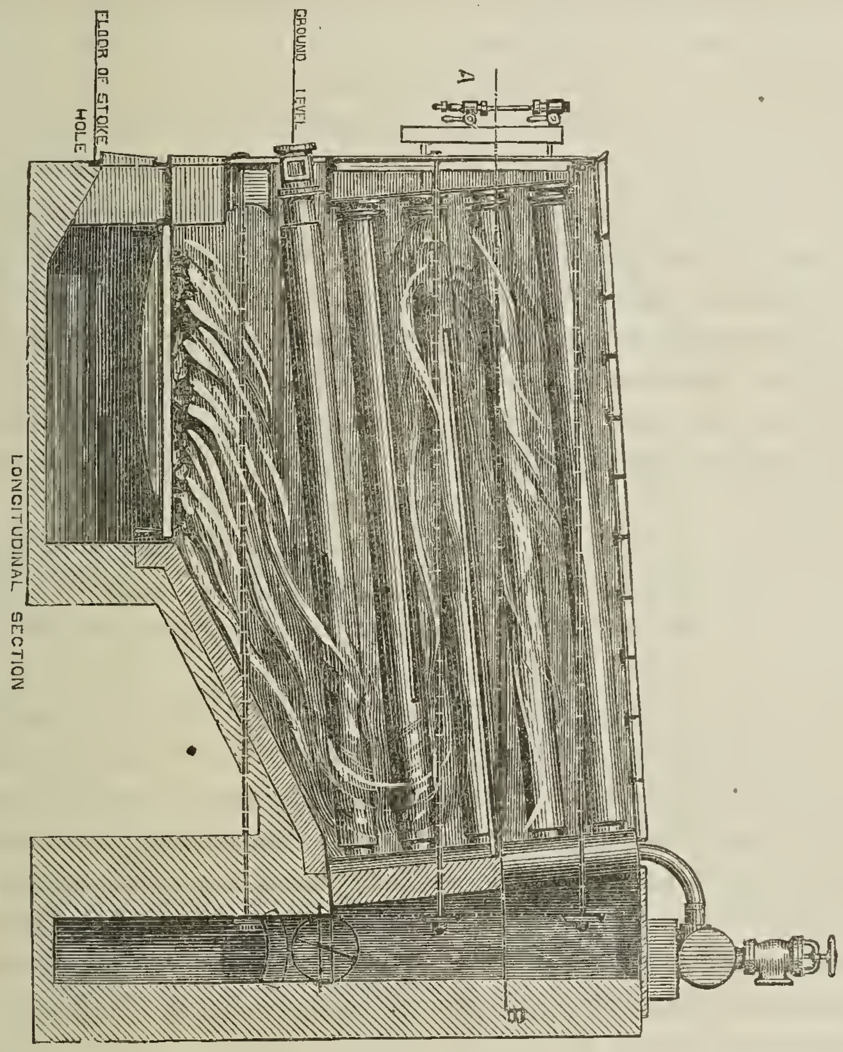

Fig. 61.—The Howard boiler—longitudinal section.

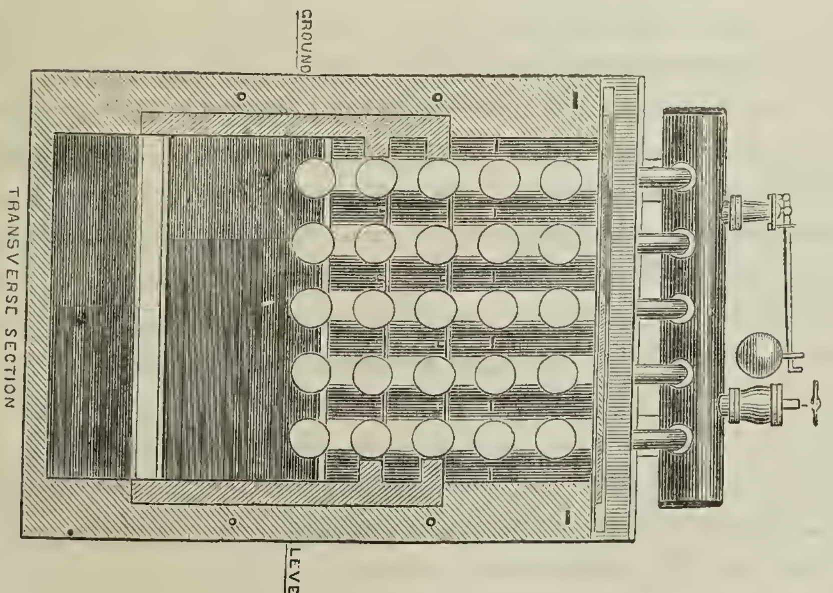

Fig. 61*a*.—The Howard boiler—transverse section.

tical tubes, which formed the only communication between them. The water-line in this boiler crossed the second row of tubes, leaving the top row and a part of that next below as a reservoir for steam and a superheater, or, more properly, a "steam-drier." The grate is below the tubes and the gas is caused to wind among them, pursuing a rather circuitous course to the chimney by means of baffle-plates laid horizontally between the layers of tubes. Messrs. Howard were said to give about 20 square feet of heating-surface and one-half square foot of grate for each horse-power. As the term "horse-power" applied to a steam-boiler has no definite meaning, it is uncertain whether this is a liberal allowance or not. Assuming the horse-power to represent the evaporation of one cubic foot of water per hour, as in the table above given, this allowance would seem none too great.

The boiler is simple in construction, very strong, and injured tubes can be quite readily replaced. It is said to make steam freely and quite steadily, and is looked upon as a good example of this class of steam-boiler.

139. The Messrs. Howard state that every boiler is tested to three times its working pressure, and that the bursting pressure of the tubes is at least 1,500 pounds per square inch. They claim for it great simplicity of parts, facility of repairs, and durability, as well as safety. They add that in the Howard boiler there are neither seams nor rivets, and no joint is exposed to the direct action of the fire; the tubes are counterparts of each other, and every part is made on the interchangeable principle, and it is more readily accessible, both internally and externally, for thorough inspection and cleaning than almost any other form of boiler; and that, with their boiler, a pressure of 120 to 140 pounds per square inch is more secure than ordinary boilers working at 50 pounds; while experience has shown that, on the great question of economy of fuel, the hopes entertained that the higher pressure of steam would, under proper conditions, lead to an important saving of coal, have been realized. This boiler in many instances, on a large scale, is working with great economy. The boiler can be taken to pieces and carried in ordinary railway-trucks. For exportation it can be packed in a very small compass, and can be transported on bad roads and through mountainous districts. The space occupied by the boiler when fixed is little more than half that required for a Cornish boiler of the same power, and the principle admits of boilers being constructed so as to suit almost any position. The brick-work setting is plain. Where there is only one boiler, it is set between two straight brick walls; where there are two or more boilers, a dividing wall is all that is required in addition.

These boilers have now been in use nearly seven years. They have been applied to nearly every purpose for which steam-power is required, and have been working under varied conditions and management. These facts are offered as good evidence that the principle of the boiler has been appreciated, and as proof that a large amount of practical success has been achieved.

Messrs. J. & F. Howard constructed in January, 1866, for their own works, a boiler of 40 horse-power, upon the tubulous principle. After many experiments with both vertical and horizontal tubes, conducted with care, and after some improvements had been effected, other boilers on the same principle were fixed, replacing Cornish boilers previously in use. The results of their working were so satisfactory that they were led to direct public attention to this form of boiler, and the experience of the last six years has, as they affirm, confirmed their expectations and proved the utility of the boiler for almost every purpose for which steam-power is used. Many engineers and manufacturers, both at home and abroad, have adopted them on a large scale.

140. A somewhat similar steam-boiler, called the "SINCLAIR boiler," exhibited by McNicol, of Glasgow, is made up of smaller tubes, and resembles still more the boiler of the Root Steam-Engine Company.

141. The finest boiler-work in the collection was seen in the boilers of Messrs. ADAMSON & Co. They were similar in size to the Galloway boilers, each 24 feet long and 7 feet in diameter. Two were set and were at work. One is of iron and the other of steel. The shell of each is riveted, but the flues have welded longitudinal seams, and are made by flanged joints, which serve as both expansion-joints and strengthening-rings. The main flue is stayed, like the Galloway boilers, with cross-tubes, which are welded in place instead of being riveted. Specimens of these tubes, welded in a short length of flue, were exhibited separately, and were extraordinarily fine pieces of work. It was in some cases very difficult to find the weld. All of the work on these boilers was most excellent, and is such as is rarely seen, either in Europe or America. Thoroughly good boiler-work is rarer than good machine-work, and deserves especial commendation when found.

142. THE DAVEY-PAXMAN BOILER, (Figs. 63, 64,) exhibited with a portable engine, (Fig. 62,) is worthy of notice. It is a vertical boiler, having a set of bent and tapering tubes in the fire-box, as shown in the sketch. The London Engineer, to which we are referred by the exhibitors, thus describes a trial of this boiler:

"The engine being a 4 horse-power, nominal, it was determined that, to make the test fair, the boiler should be fired as though the engine were working at 6 horse-power, and it was calculated that such an engine would use about 40 pounds of steam per horse-power per hour, therefore that the boiler must be called upon to evaporate 240 pounds of water per hour. The experiment actually lasted 3.5 hours, and the total evaporation was 798 pounds, which, divided by the running time, gives the hourly evaporation as 222.25, very nearly. * * * The boiler evaporated 9.5 pounds of water per one pound of coal, a result which we believe to be almost unprecedented with a vertical boiler of these dimensions. * * *

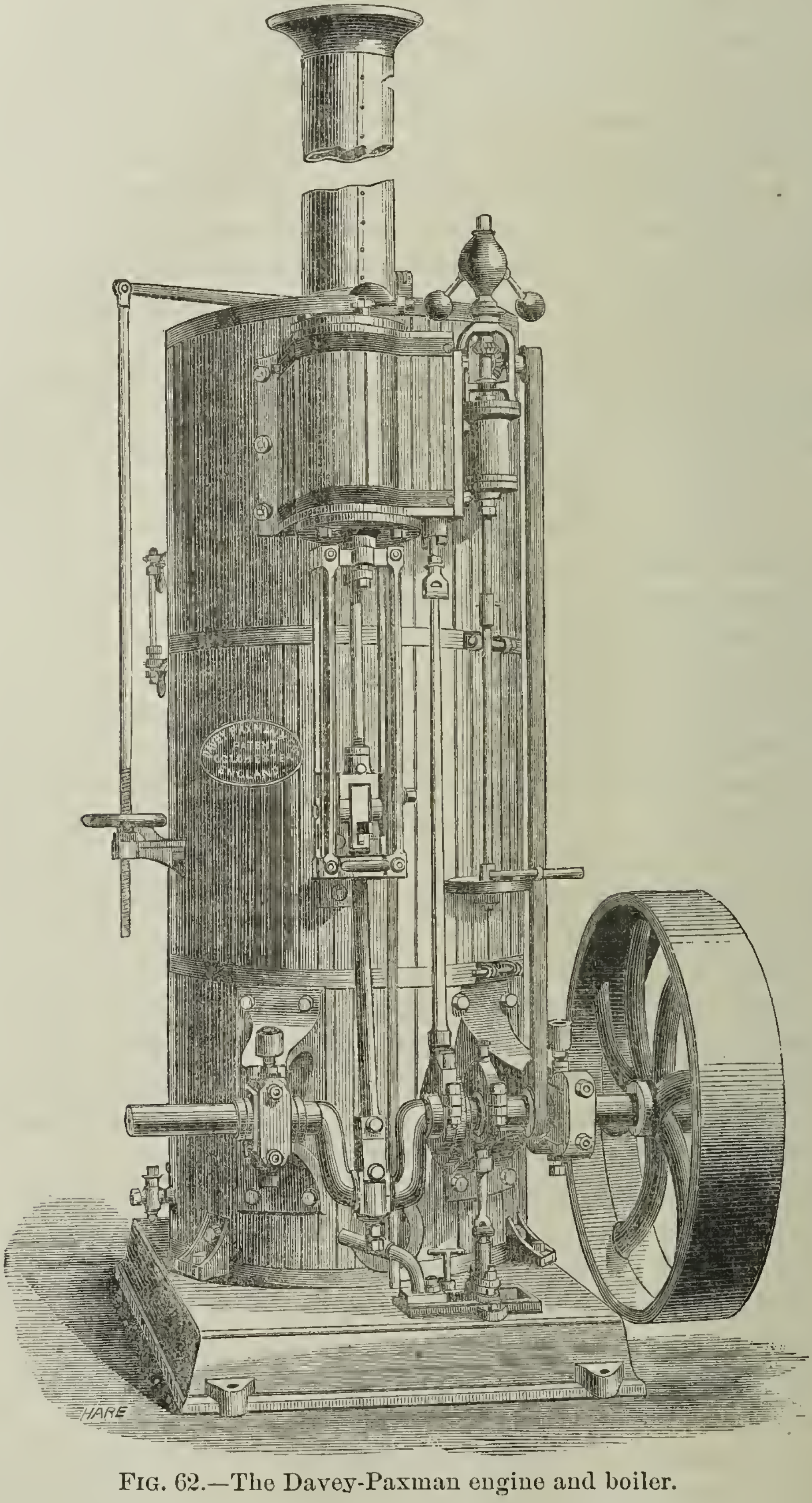

FIG. 62.—The Davey-Paxman engine and boiler.

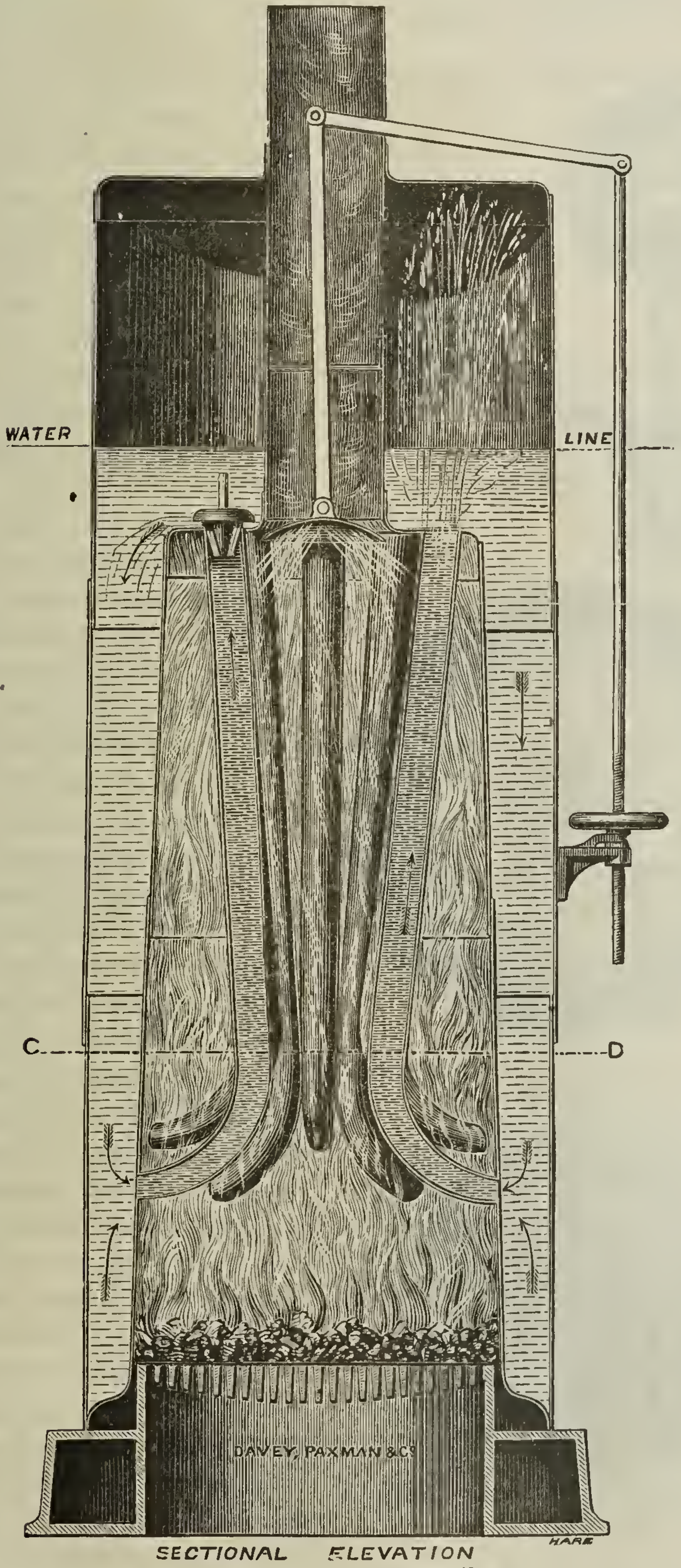

Fig. 63.—Davey-Paxman boiler.

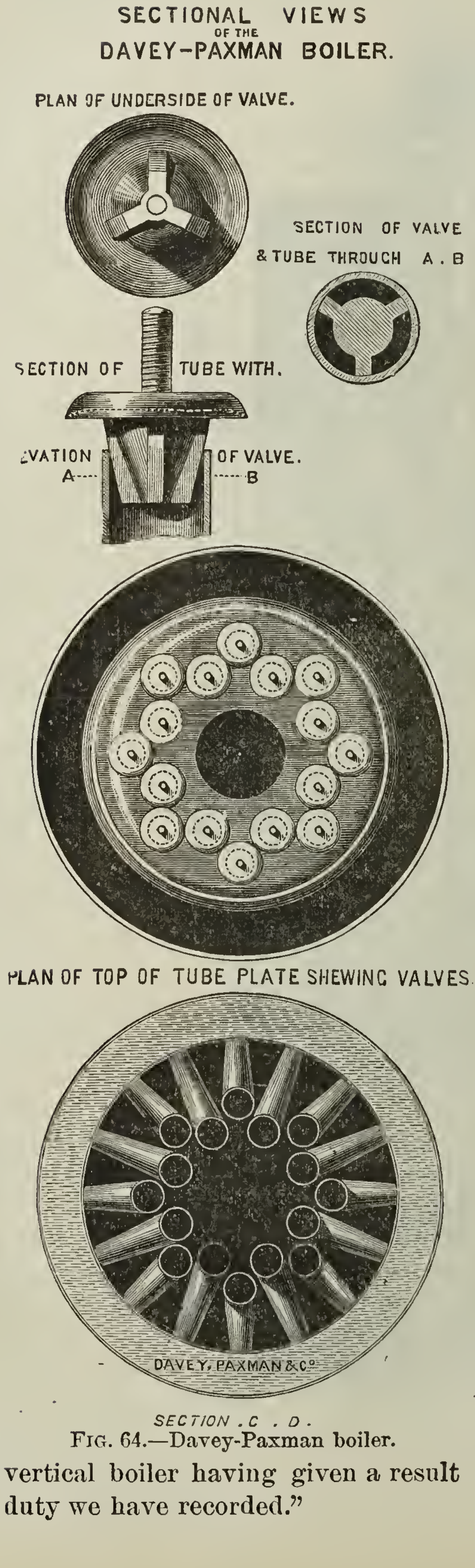

Fig. 64.—Davey-Paxman boiler.

"We confess that this experiment tends to modify the views we have already expressed concerning vertical boilers. We have here a vertical boiler doing better than the Royal Agricultural Society's boiler, generally admitted to be very good. It will be seen from the judges' report that this last evaporated, with excellent Welsh coal, only 9¼ pounds of water per pound of coal, while the Davey-Paxman boiler evaporated 9½ pounds with common coal. With the Welsh coal we have no doubt whatever that it would have evaporated 10 pounds of water, a result which we do not hesitate to say has seldom, if ever, been attained in any experiment conducted with small boilers, and carried out with the care bestowed on the trial, the particulars of which are just given."

London Engineering of October 14, 1870, speaking of the best vertical engines at the trial at the Royal Agricultural Society's show at Oxford, says: "The evaporation of water per square foot of heating-surface was 1.48 pounds, a rate of evaporation less than one-half as great as that obtained with the Davey-Paxman boiler. As regards the amount of water evaporated per pound of fuel burned, the Davey-Paxman and the Royal Agricultural Society's boilers are almost exactly equal. These results show that the Davey-Paxman boiler possesses an evaporative efficiency equalled by but few boilers of any class whatever, and we certainly have no authentic records of any other vertical boiler having given a result approaching at all closely to the duty we have recorded."

The Mechanics' Magazine of December 9, 1871, remarks: "It will be seen that the merits of this boiler are due to the bent and taper water-tubes and the deflector inserted in the top of each tube. The water in these tubes, being exposed to the full heat of the furnace, soon acquires a much higher temperature than in the other parts of the boiler, and rises rapidly. The water from all the other parts rushes into the tubes, and thus keeps up a constant and perfect circulation. The taper form at the lower end adds greatly to the velocity and the scouring action that takes place in the tubes and all parts of the boiler. So great is the velocity of the water through these tubes that it rises in jets completely up to the crown-plate. This would of course render the boiler useless, but for an ingenious contrivance invented to keep the water perfectly smooth on the surface. This is the patent deflector, plan, section, and elevation of which are shown in the engraving. These deflectors, placed at the top of each tube, arrest the jets of water, divert them downward with increased velocity, and cause the water to impinge upon the sides of the boiler and tubes. This latter contrivance effectively prevents priming, hitherto a great drawback to the use of vertical boilers. There is a baffle-plate, adjustable by hand on the outside of the boiler, which regulates the heat and throws it back among the water-tubes just where it can be most profitably utilized. These boilers not only contain nearly twice the heating-surface of an ordinary boiler, but this heating-surface is of the most advantageous kind, consisting largely, as it does, of thin tubes exposed to the extreme heat of the furnace. Their thinness has a great advantage. They permit the free transition of heat, and are less affected thereby; and as no incrustation takes place, they will last as long as the shell boiler."

This boiler is not a novel device. The writer had his attention called to this form of tube and fire-box by an American steam fire-engine manufacturer fifteen years ago.

143. The BELLEVILLE BOILER, exhibited in the French section, is another form of sectional boiler, and seems to be the only one which has become well known in that country. It is, with the exception of the Root boiler, the only sectional boiler which has been well tried at sea with fairly satisfactory results, as far as the writer can learn. It has been used to some extent in the French navy. In general construction, this boiler resembles somewhat the Howard boiler. It consists of a mass of water-tubes, connected together at each end by cast-iron boxes, through which circulation may take place. The tubes are 6 or 7 feet long, 2½ to 3 inches in diameter, and usually of about No. 3 gauge.

A Belleville boiler was exhibited in the Belgian section. These boilers seemed well proportioned, well built, and of good material. They have given excellent results where they have had sufficiently prolonged trial to justify a report.

144. Germany was represented in this department by eight exhibits. J. C. C. Meyn's boilers are made with two cylindrical shells, the one

superposed on the other. The two exhibited at work had the following dimensions: Diameter of shell, 75 inches in the lower and 52 inches in the upper portion; length of shell, 8⅓ feet in the lower, 6½ feet in the upper boiler; heating-surface, 431⅓ square feet; grate area, 15½ square feet. The grate was 6⅜ feet long; the tubes were flattened vertical water-tubes below, 74 in number, with 66 cylindrical tubes above, of 2½ inches diameter. The pressure proposed for these boilers was 60 pounds per square inch. They were well made, machine-riveted, and seemed of good iron. The exhibitors gave as the results of trial of a somewhat smaller boiler, using coal containing about 80 per cent. carbon, and 3½ per cent. hydrogen, and making 15 per cent. ash, an evaporation equivalent to from 7¾ to 9¼ pounds from the boiling-point, or an efficiency, estimated as in the trials of the American Institute, already given, of 55 to 65 per cent. The agent of M. Krupp, at Vienna, stated that these boilers were in use at Essen, and were found to perform very satisfactorily.

145. EHRHARDT'S BOILER.—The designer of the so-called "Dingler engine," Herr Ehrhardt, exhibited a steam-boiler, built also by the manufacturers of his engine, the Dingler'sche Maschinen-Fabrik, of Zweibrücken. This, too, is a double construction, two shells connected by vertical cylinders, one at each end; the larger was 3¼ feet in diameter, 11½ feet long; the upper and smaller was 3 feet in diameter. The heating-surface was given at about 350 square feet; grate-surface 11½ square feet. A feed-water heater was attached, containing about 65 square feet of surface. A "mud-drum," about 20 inches in diameter and 15 inches deep, is placed beneath the boiler. The inventor presented members of the International Jury with a little pamphlet-circular, in which he explained very fully his ideas with reference to the practice of steam-boiler construction. He is a believer in slow combustion, small boilers, and many of them, where it is necessary to obtain a large quantity of steam. He proposes burning but nine or ten pounds of coal per square foot of grate per hour in stationary boilers, and prefers not to construct boilers having more than from 300 to 400 square feet of heating-surface, considering several small boilers better than the same amount of heating-surface in a less number of larger boilers. He thinks two meters too long for a grate-bar and a meter to be a maximum width. About one square meter is his best area of grate. He prefers to make fire-box boilers.

The boiler exhibited furnished steam to the compound engine already described. (Art. 41.) It was designed for a pressure of 150 pounds per square inch, or ten atmospheres, as pressures are reckoned in Europe.

146. JULIUS BERGMAN, from Haltingen, Westphalia, exhibited two steam-boilers, each composed of an upper and a lower cylindrical shell, with a detached furnace of brick-work. The upper shell was about 4½ feet in diameter, and 5½ feet high, and from its lower head a set of vertical dependent water-tubes were carried down around the lower shell, which was but about 2½ feet in diameter, and was 10 feet high. These

tubes, 45 in number, were 3 inches in diameter and 4 feet 8 or 9 inches long. Brick-work surrounded the boiler, and guided the gases *en route* to the chimney. The advantages claimed for the boiler were economy, durability, accessibility for repairs, and great strength of form. Its economy, however, was not established by any results of trial furnished the jury; in durability it might claim advantages were it not for the unfortunate arrangement of setting incident to its form, which certainly did not justify a claim of accessibility. Its strength is simply a question of thickness of iron and diameter of shell. The boiler introduced by Corliss in the United States possesses some features resembling the details of this boiler, but is far superior to the German design in most respects.

147. PAUCKSCH & FREUND are the German patentees of another boiler, of which type two were exhibited in the German section. They were 7½ feet in diameter and 17 feet long. Each contained 90 tubes 3½ inches in diameter, and fastened in place by Berendorf's apparatus. The boiler was externally fired, the furnace having a brick arched top, which separated it from the boiler. There were some peculiarities of construction which should be noted, as interesting and sometimes evidently commendable. Flanging was resorted to wherever other builders usually introduce angle-iron connecting-pieces; the holes in the tube-sheets were tapered, and the tubes were given a similar shape; the tubes were clustered in two sets to enable a workman to enter among them for cleaning. Accessibility was secured inside and out, most fully.

The agents state that, at a trial in Silesia, one of these boilers with a heating-surface of between 1,300 and 1,400 square feet area, a grate-surface of one-fiftieth that extent, an evaporation of over 8 pounds of water per pound of coal was obtained, where a Cornish boiler of usual proportions evaporated but 6 pounds. In another case an evaporation of about 10 pounds was reported. The latter, if correct, is creditable the former is not remarkable.

148. SIGL'S BOILERS.—In the Austrian section, SIGL, of Vienna, exhibited three well-made boilers of the form familiar to all engineers who have studied French designs, as the "Chaudière à Bouilleurs." They consisted of a large cylindrical shell 4½ feet in diameter and 35 feet long, beneath which were a pair of "bouilleurs," each 2½ feet in diameter and running nearly the whole length of the longer portion, to which they were attached by vertical connecting-pipes 1½ feet in diameter. The heating-surface measured about 700 square feet; the grate-surface, 20 feet. The pressure proposed for them was 5 atmospheres. They were fitted with Zeh's mechanically fired furnaces. In this arrangement th grates are inclined, and the fuel glides down them from a hopper, urged by gravity and aided by a motion given by eccentrics or a shaft driven by the donkey-pump. Some very favorable testimony was given in regard to the action of these grates.

BOLZANO, TEDESCO & CO., of Prague, exhibited a double boiler consisting of a lower multitubular boiler, about 6 feet in diameter and 10½ feet long, containing 85 tubes of 3 inches inside diameter, and of an upper plain cylindrical shell 3 feet in diameter and 15 feet long. The grate was of Bolzano's patent, 27½ square feet area, 6½ feet long, and 4¼ wide.

These boilers were in brick settings, which were somewhat expensive in character, and in arrangement were capable of improvement.

Bolzano's grate and furnace door attracted much attention, and deserve notice from that fact, even if not proven to be of exceptional excellence. The former consists of a double set of grate-bars inclined at an angle of 12° or 15°, and a third set lying beyond and below them some 30 inches below the boiler in a horizontal position. The latter are cast in one piece. In the inclined sets, alternate bars are movable and may be raised a short distance, at the inner ends, by means of a properly adjusted lever, thus breaking up the cinder and cleaning the fire.

The horizontal grate may be drawn out by means of an attached rod whenever it is desired to remove the cinder. The furnace-door carries on its upper part a kind of hopper or trough, into which coal is thrown, and where it remains until required on the grate. The fire being started, and the fuel worked down by shaking with the lever attached to the inclined bars until it reaches the horizontal grate, it is allowed to burn until so far consumed that it becomes necessary to add fresh fuel. The fuel already placed in the hopper is then thrown upon the upper set of inclined grates by tilting the hopper on the horizontal spindle which carries it, and the hopper, falling back into its usual position, is again charged with fresh coal. The fuel is thus worked down until it is finally completely consumed, the cinder forming a deposit in the lower horizontal grate and the ashes falling through the grates into the ash-pit. The cinder is finally removed by withdrawing the flat grate and dumping it into the ash-pit. Thus, it is claimed, a uniform temperature and a clear fire, with rapid and regular combustion, are secured with fuel of very inferior quality. The apparatus is simple, inexpensive, and, with a little experience and care on the part of the attendant, is said to be very efficient.

149. FEED-WATER HEATERS.—The use of feed-water heaters in connection with non-condensing engines is very usual in the United States. It is less frequently seen in Great Britain, and still less often on the continent. They are of many forms, but may be divided into two classes: those in which the steam comes directly into contact with the feed-water, as in the "open heater" generally used in some parts of the country, and those in which the heat is transferred by conduction through metallic walls separating the steam from the feed-water. The former are the least expensive, usually, and are the most efficient as simple transferrers of heat; but they allow all grease and impurities coming over with the steam to be mingled with the feed-water, and they give some trouble frequently, in consequence of the difficulty of

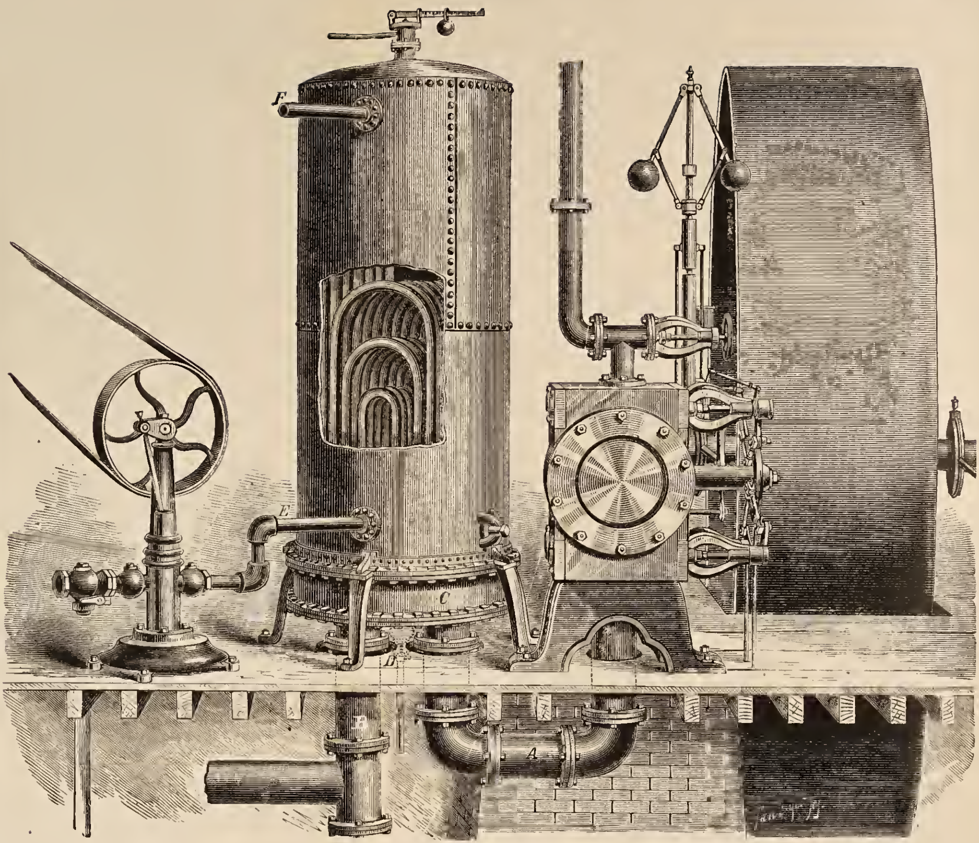

FIG. 65.—The Berrymen feed-water heater.

drawing from them and forcing into the boiler the heated water. The feed-pump must be placed so low as to have a sufficient head of water to open its valves; or the temperature of feed must be kept low enough to permit the formation of a partial vacuum and the lifting of the valves by atmospheric pressure; or they must be operated automatically, with a head on the pump sufficient to produce the flow of water through the induction-passages at the speed required for the prompt filling of the pump at each stroke. The closed heater gives less effective heating; but it preserves the feed-water pure, and the pump ma draw in the usual manner and force through the heater, thus avoiding the objections to the open heater.

The economy due to the use of a heater for the feed-water is not always fully appreciated either by designers, manufacturers, or users of steam-boilers. It is so easily calculated, however, that no one need remain in doubt as to the advisability of their use in any given case.

If T represents the total heat of steam at the boiler-pressure, estimated from 0°, t=the temperature of the feed-water entering the heater, t'=the temperature of the feed-water leaving the heater and entering the boiler, the economy secured by the use of the heater is—

$$E = \frac{t' - t}{T - t}$$

For example: If the total heat, T, is 1,200° Fahr., and the temperatures of the feed before and after entering the heater t and t' are 50° and 200°, respectively, the gain is—

$$E = \frac{200^\circ - 50^\circ}{1{,}000^\circ} = 0.15, \text{ or 15 per cent.}$$

This is a fair illustration of the gain to be obtained by the use of a good heater in cases of very common occurrence, and 15 per cent. of the coal-account is usually a very important item.

The Berryman heater (Fig. 65) was one of the best, if not the very best, exhibited at Vienna. It is illustrated in the accompanying plate, as attached to the exhaust-pipe of a Corliss engine.

It represents the heater with a portion of the shell broken away, so as to show the position of the steam-pipes within. A cylinder contains the feed-water, E being the induction and F the eduction pipe. The exhaust steam enters one side of the chamber through the pipe A; it is thence conveyed by the tubes to the other side of the chamber, and passes out through the pipe E. D is a blow-off cock, connected with the feed-water cylinder, and two drip-pipes are connected with the exhaust-chamber E. The construction of the water-cylinder, which is made strong enough to withstand the working-pressure of any steam-boiler, will be understood readily from the engraving. The tubes used are seamless brass of the best quality. They do not pass through the sheet, but rest upon a shoulder formed in boring it, and are there expanded or set up. A sufficient number of tubes are employed in each heater to obtain an area in the aggregate twenty per cent. greater than that of the exhaust-pipe of the engine for which it is intended.

Among the advantages claimed for this form of heater are the following:

The ability of the steam-tubes to expand and contract with varying temperatures without causing the damaging strains to which heaters that are constructed with tubes fastened in both heads are subject.

The capacity of the heater for containing a large quantity of water, which insures sufficient time for it to become settled and thoroughly heated before being fed to the boiler.

The arrangement of the supply-pipe and feed-pipe, (the first being near the bottom of the heater, but far enough distant from the constantly collecting sediment to create no disturbance in it, and the second near the top,) which results in supplying the boiler with pure water at a maximum heat.

The facilities for cleaning the heater.

The advantage of requiring but one pump, when open heaters require two, which occurs in all places where there is no water-pressure; it avoids the constant trouble and risk of overflowing into the exhaust-pipe to which all open heaters are subjected.

The feed-water reaches the boiler at a temperature nearly equal to 212° Fahr., and this high result is due to the large amount of heating-surface obtained and the constant passage of the exhaust steam through the tubes, which takes place whether the boiler is being fed or not. There is no place in which the water of condensation can lodge in the tubes, and there is therefore no loss of power, which would otherwise be incurred in driving it through them.

The steam and feed-water not coming in contact with each other, the arrangement prevents injury to the boilers. By carrying so large quantity of water heated to nearly a boiling-point, it adds largely to the steam-producing capacity of the boilers. It purifies impure water.

The apparatus is simple, and a vast amount of testimony was presented indicating its efficiency. The advantage claimed of freedom from liability to leakage of joints produced by irregular expansion is a very important one. The makers recommend with propriety the use of a large heater, and its expense is usually fully compensated by its superior efficiency. Surfaces are rarely too greatly extended in either boilers, heaters, superheaters, or surface-condensers. Its greater capacity also permits the settlement of mechanically-suspended impurities and the precipitation of those lime-salts which are thrown out of solution by raising the temperature of the water in which it is dissolved.

The BERRYMAN FEED-PUMP REGULATOR was also exhibited and received very general commendation. Its positive and invariable action and the evidently common-sense principles upon which its design is founded were alike subjects of favorable comment. It is simply a cast iron sphere of moderate capacity, suspended from a steelyard balance. It is connected with the water-space by two pipes of small diameter, one of which terminates just above and the other just below the proposed water-line. When the water falls, steam enters the upper pipe and fills the globe. The weight of the unloaded vessel is insufficient to counterbalance the opposite weight, and it falls, putting on the feed as it descends. When the feed has entered in sufficient quantity to raise the water-level above the mouth of the upper tube, water ascends through that tube into the globe, taking the place of the steam as the latter condenses, and the weight of the now filled vessel causes it to descend, shutting off the supply of feed.

There is evidently some loss by condensation of steam, but that can well be afforded when safety is so well insured. The only risk of failure of the apparatus occurs when the pipes become choked by sediment, or when the friction of the feed-attachments becomes so great as to prevent motion. Either would be a consequence, in exceptional cases, of want of care. The writer has had gauge-cocks attached to the pipes of such arrangements, and they serve the double purpose of furnishing an independent means of determining the position of the water-level and of keeping the pipes clear.

H. N. WATERS'S FEED-WATER HEATER, another American invention, was also exhibited by the inventor, a resident of Hartford, Conn. This consists of a tank, closed and fitted with pipes leading into it the exhaust steam and the feed-water, and affording exit to the latter and to waste steam or water. The steam is guided by a deflecting plate, and the cold water, as it enters, is sprinkled by a rose or a perforated pipe; a very complete intermingling is thus secured. The water stands within at a height which is indicated by a gauge-glass on the exterior of the tank. The eduction-pipe, leading to the pump, is cut short a few inches above the bottom in order that the sediment may not be disturbed by the issuing current. The pump draws air when the water-level falls below this point. This is, as seen, an open heater, and cannot be safely used when the water contains matters in suspension or solution which are likely to injure the boiler. These heaters were both exhibited in the British section.

Several "economizers," as their inventors call them, were also exhibited as original inventions by British exhibitors. The economizers of Green and of Twibil are collections of pipes, which seem to be usually made of cast iron, and look much like what would be called in the United States sectional boilers, which have been inverted in application. They are heated by waste gases from the boiler, and are intended to be used to increase the economy of the less efficient forms of boiler. They are provided with scrapers to remove the deposits of soot from the exterior of the tubes, which are so liable to form wherever bituminous coal is used as fuel. The apparatus of both inventors is well made and well put together, can be conveniently kept clean, and are said by those who have used them to be very valuable accessories.

Such apparatus may very frequently be used with great advantage in cases in which the boiler is deficient in heating-surface or in which the surface is badly arranged, wherever, as is not unusual, the gases escape from contact with the boiler at temperatures much above that of the boiler itself, and where, at the same time, the draught is amply sufficient to produce the required rapidity of combustion after the addition of such a retarding influence.

The economy to be derived by its application is calculated as in the case of exhaust feed-heaters. Mr. W. A. Miller and other engineers in the United States have for many years adopted this method of increasing economy. The writer, in the course of professional work, has often found their use to make an utterly inefficient steam-boiler quite as economical as the best known types.

150. INJECTORS.—FRIEDMANN'S INJECTOR was one of the most important attachments to steam-boilers exhibited. It was attached to several locomotives, and is in extensive use all over Europe. The proprietors state that over 12,000 are in use in Europe, and that Messrs. Nathan & Dreyfus, of New York, are now introducing them into the United States. They urge in their favor the advantages that they start punctually, do not reduce the steam-pressure when at work, feed either warm or cold water, and have no movable parts to get out of order.

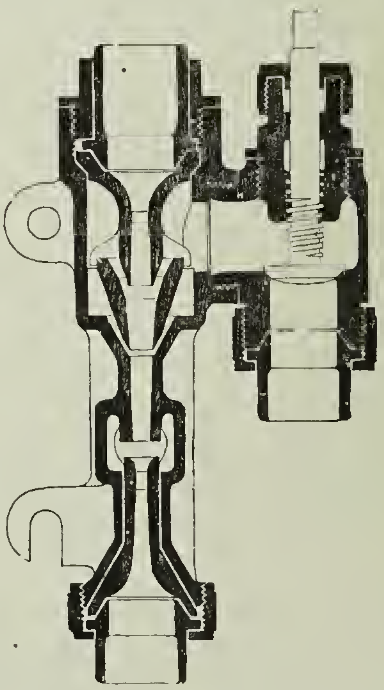

Fig. 67.—Friedmann's non-lifting injector—section.

Fig. 66 represents one of these injectors as attached to a locomotive. A is the starting-valve; B, the steam-pipe; C, the water-supply pipe; D, the water-delivery pipe; E, the overflow pipe; F, the check-valve; G, the water-regulating handle; H, the overflow-valve handle; O, the overflow-valve; W, the water-valve.

One of the peculiarities of this form of injector is the intermediate nozzle, seen in Fig. 67, which permits the water to be supplied to the steam-jet in two annular streams, giving a smoother reciprocal action

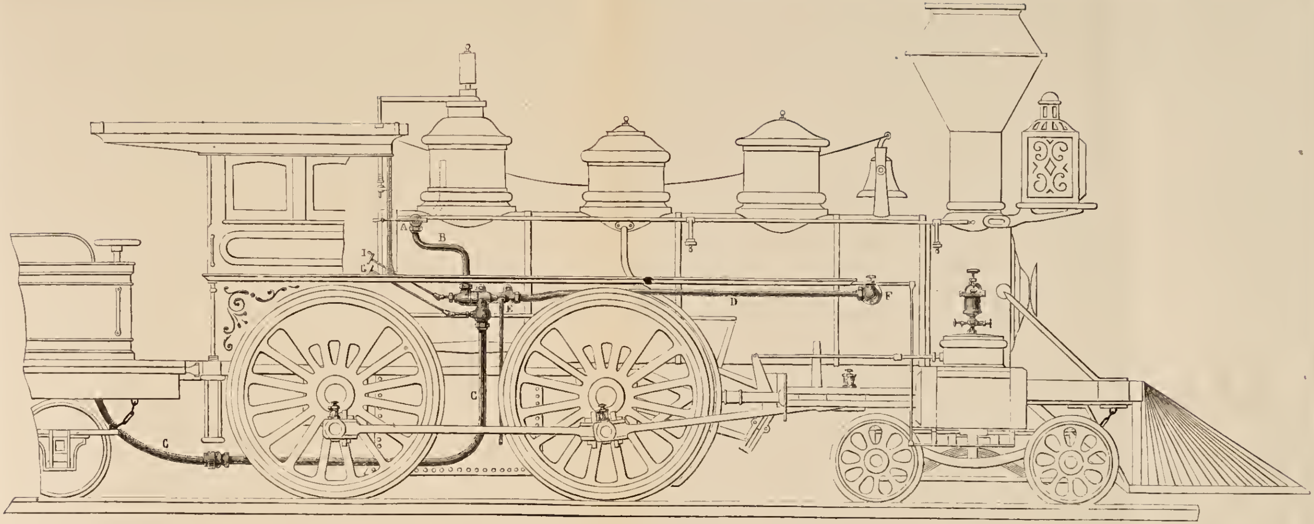

FIG. 66.—Friedmann's non-lifting injector on a locomotive.

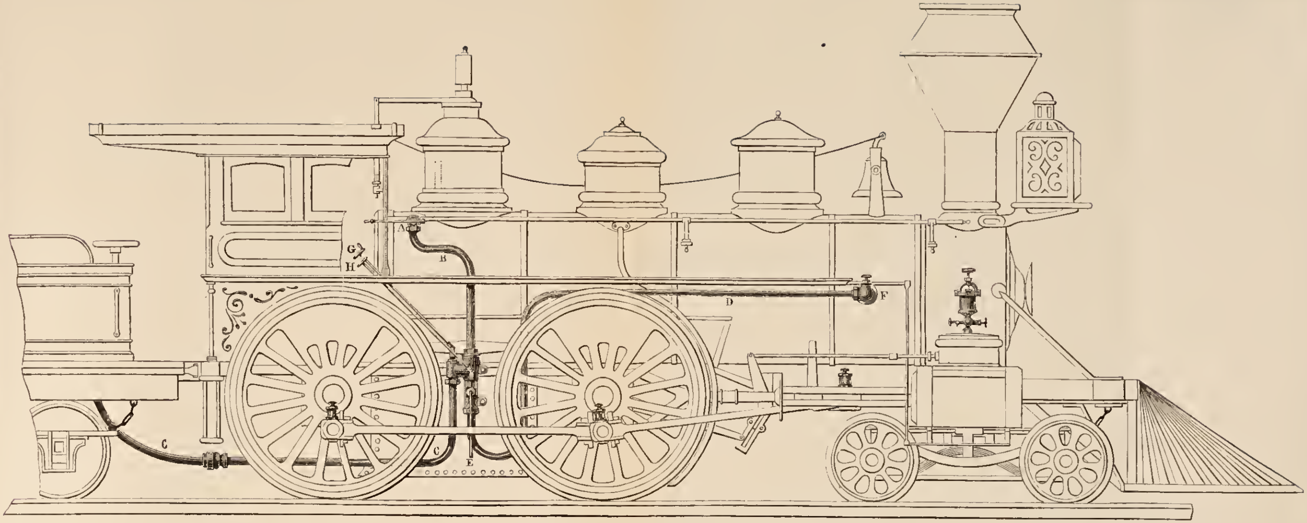

Fig. 68.—Friedmann's lifting injector on a locomotive.

of the two currents upon each other. Another merit of the device is that the overflow from the one nozzle flows down outside, already warmed, and forms a part of the supply to the second. Acting upon the current of water at two points, the steam imparts its energy very equably, and itself becomes perfectly condensed.

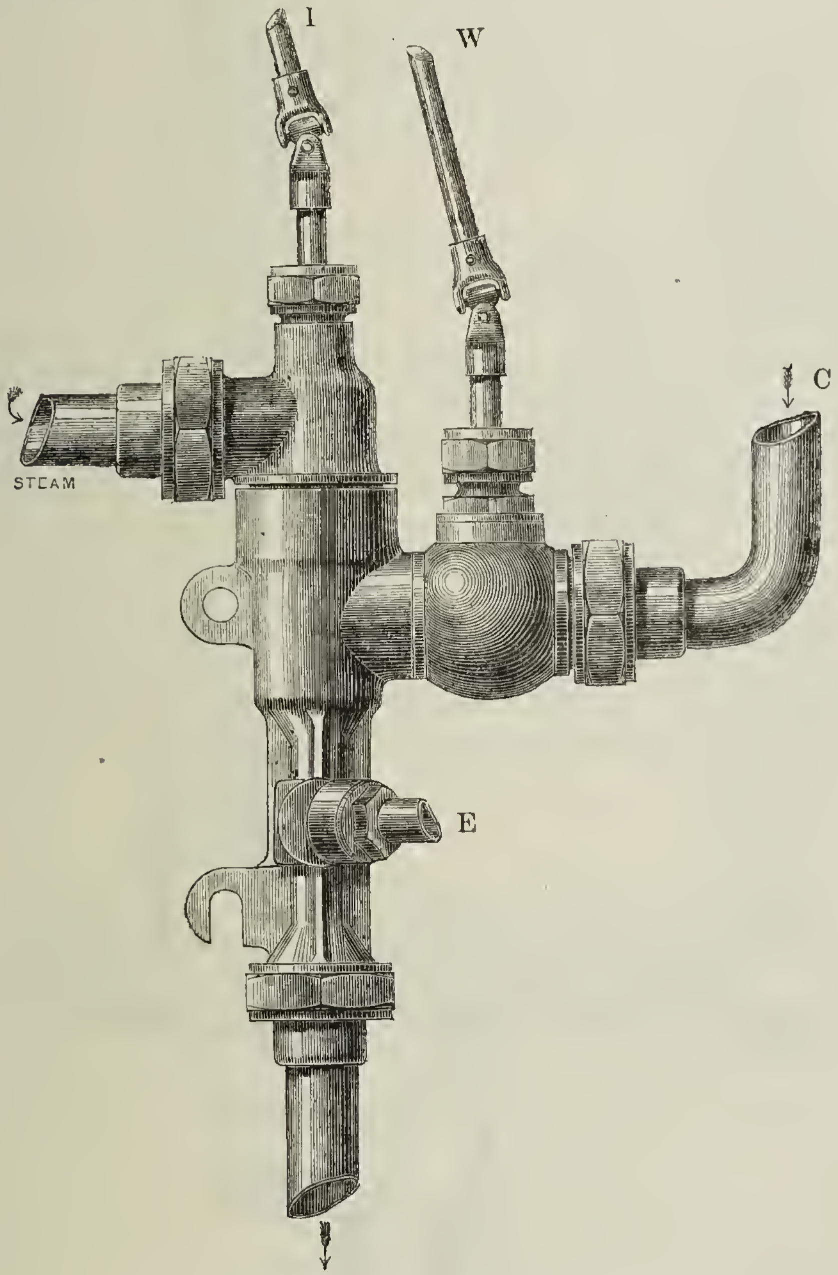

Fig. 69.—Friedmann's lifting injector.

The non-lifting form of injector is placed before the source of supply. It is sometimes used as a heating-cock, simply by closing the overflow and permitting the steam to flow into the tank. In attaching this, as with all injectors, the pipes must be made as short, large, and direct as possible. In working, the overflow-valve is opened by the handle seen in the engraving; the starting-valve is opened, first gradually, then as rapidly as may be; the overflow is then adjusted until no waste of water occurs, and the machine is in full operation.

The lifting injector is shown attached to a locomotive in Fig. 68. It is placed horizontally instead of vertically, and may be used for lifts of 8 or 10 feet. This form has been set up to lift 18 feet vertically. The exterior is shown in Fig. 69, in which I is the steam and W is the water-valve; E, the overflow; C, the water-supply, the upper nozzle the steam and that at the bottom the boiler attachment.

Fig. 70 exhibits the interior of this instrument, in which I is the steam and W the water valve; B the steam, C the water, and D the boiler-pipe nozzles.

Fig. 71 illustrates one of these injectors as proposed for stationary boilers. It stands vertically, and will work up to a temperature of feed-water of 140° Fahr.

Fig. 72 is a style used for portable, stationary, and small marine boilers. It is similar in general internal construction to the others. It is intended to be capable of lifting readily from 8 to 10 feet.

The Giffard injector, invented a quarter of a century ago by Henri Giffard, of Paris, was the first of this class of instruments. Its remarkable power of taking steam from one point in a steam-boiler and returning it to the boiler again at another point, loaded with many times its weight of water, and without the movement of any one of its own organs, was at first a paradox to many, even well informed, engineers. It is now well understood, and is recognized as one of the most beautiful known adaptations of scientific principles to practical purposes. This principle may be easily understood: If an opening is made into the steam-space of a boiler, the steam will issue with a velocity due the pressure; and, were its motion reversed, it would be just able to return into the boiler. But suppose all the energy of the rapidly-flowing current concentrated upon a fractional portion of the section of the opening, the resisting pressure remaining constant, the stream of fluid would re-enter and would have a surplus of *vis viva* sufficient to carry with it a load of water. This is precisely what occurs in this injector. The great stream of steam issuing from the boiler is condensed in the

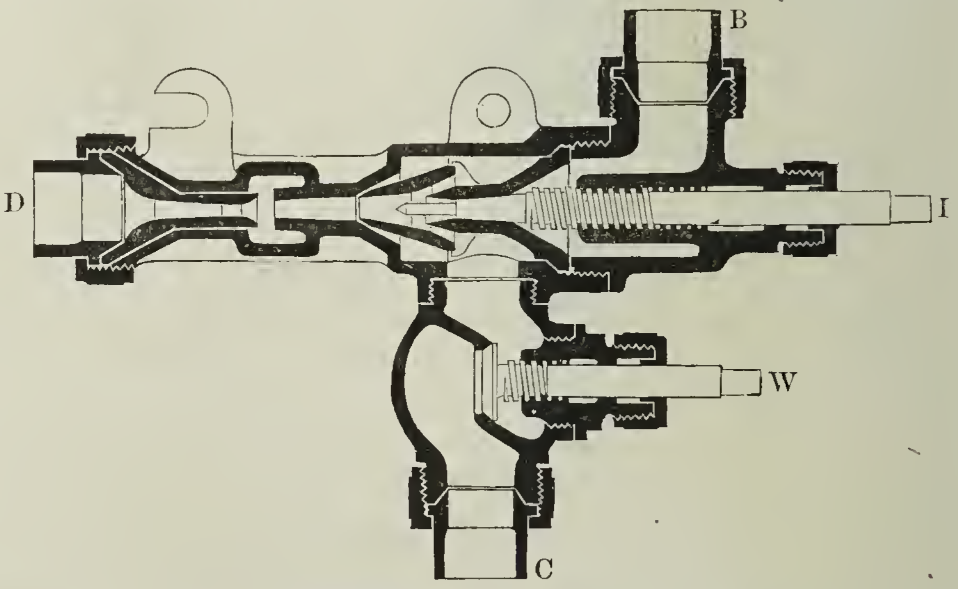

Fig. 70.—Friedmann's lifting injector—section.

instrument with a comparatively small mass of water and expends its surplus energy in carrying into the boiler the water by which it was condensed. Steam taken from one boiler has been known thus to carry its load of water into another boiler under double pressure. The amount of this surplus is indicated by the fact that a pound of steam at a pressure of 60 pounds per square inch, occupying a space of $5\frac{1}{2}$ cubic feet, condenses into $\frac{1}{350}$th of its volume, forming but $27\frac{1}{2}$ cubic inches of water.

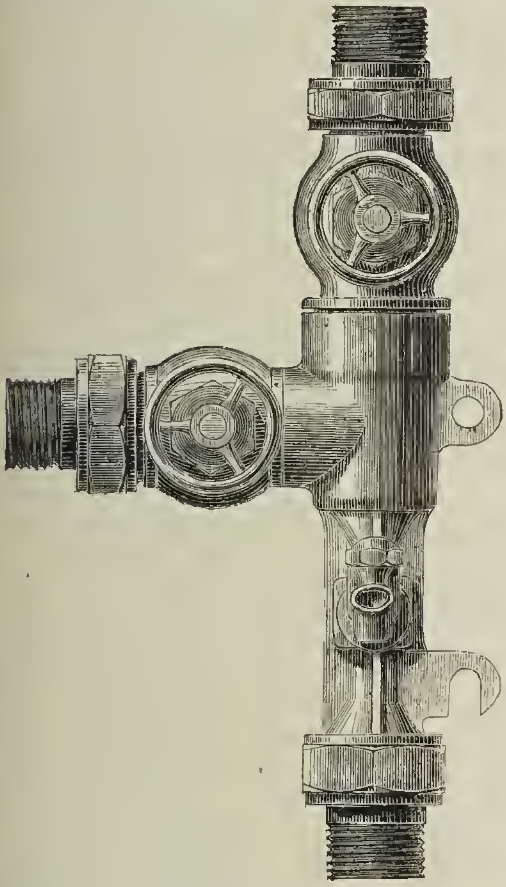

FIG. 71.—Friedmann's injector for stationary boilers.

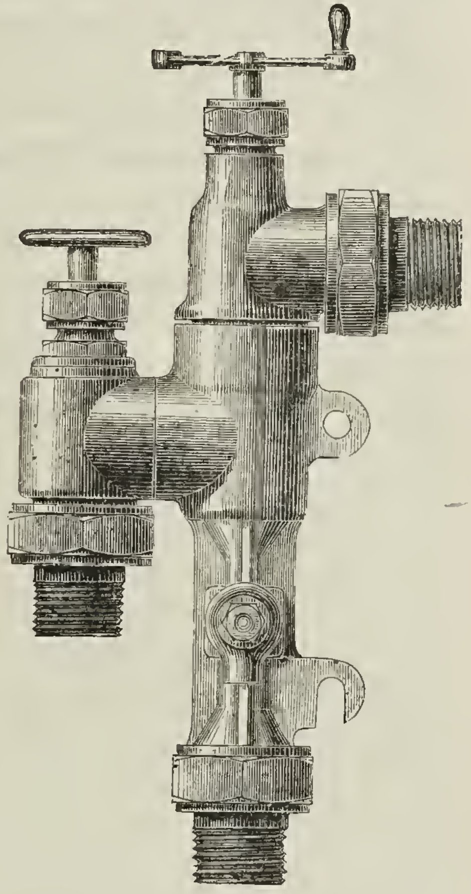

FIG. 72.—Friedmann's injector for portable boilers.

The injector is rarely used to the exclusion of the pump, but in some portions of the United States the Giffard injector, made by Messrs. Sellers & Co., with their beautiful and ingenious improvements, is sometimes found in use alone. Injectors have some decided advantages over pumps. With good water, they are far less liable to get out of repair; they are independent steam-pumps, and can be started whenever there is steam on the boiler; they warm the feed-water; they waste no steam; all that is used in them returns to the boiler again with the feed-water. They are compact, light, handy, and may be placed in any convenient place and in any desired position.

EFFICIENCY OF THE INJECTOR.—Bourne * made a series of experiments to determine the economic efficiency of the injector. As the result of over sixty trials, he remarks: "As, then, these experiments show the quantity of water evaporated from the boiler under

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* Steam, Air, and Gas Engines, 4to, London, 1869.

a determinate pressure, and also the quantity of water lifted against a determinate pressure, or head, by the volume of steam answering to the quantity of water evaporated, the duty of the instrument, in any experiment, can easily be deduced, and it will be found to be very low."

London Engineering, referring to these experiments,* takes exception to this conclusion, and shows, by a very simple calculation of duty based on Bourne's data, that the injector, although an excellent feed-pump, for the reasons given above, is not adapted to other purposes, where the heat communicated to the current is not subsequently economically applied. In feeding the steam-boiler, it is a matter of little consequence whether the quantity of steam used by the instrument in heating is small or great, as all heat not expended in mechanical work is returned to the boiler. In other cases, all heat not changed into mechanical energy is wasted.

In the examples selected for calculation, the data were the following:

Length of trial, minutes	12	9	16
Steam-pressure, pounds	30	10	30
Resisting pressure, pounds	30	10	90
Water evaporated, gallons	5	6	6
Water drawn from tank, gallons	90	94	96
Water delivered, gallons	100	100	100
Water, initial temperature, degrees Fahr.	52	60	52
Water, final temperature, degrees Fahr	117	116	114
Heat consumed, thermal units	50,266	60,245	60,320
Heat transferred to fuel, thermal units	......	52,175	57,776
Heat expended, thermal units	......	8,070	2,554

Giffard presents a brief analysis of the theory of the injector † which may properly complement the general explanation already given.

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*Engineering, July 30, 1869.

† *Notice théorique de l'injecteur automatique;* also Sonnet's *Dictionnaire des mathématiques appliquées.*

If p = the weight of steam escaping per second, P = the weight of water drawn into the instrument, m and M = their masses; ϖ = the area of cross-section of the orifice; V = the velocity of the steam at the orifice; v = the velocity of the water; a = the least cross-section of the expanding nozzle; θ = the time of mutual reaction. Then the increase of energy becomes

$$E = (m + M)\,\theta\, v - m\theta V.$$

R represent the resultant external force in line of the axis,

$$(m + M)\,\theta\, v - m\,\theta\, V = R\,\theta$$

and—

$$(m + M)\, v - m\, V = R.$$

When $R = o$, $(m + M)\, v - m\, V = o$, and, substituting weight for mass,

$$(P + p)\, v - p\, V = o$$

and—

$$p = (P + p)\frac{v}{V}$$

in which $P + p$ is the weight of water fed into the boiler per second.

Considering density unchanged, and letting S = the weight of steam per cubic meter, N = the pressure in atmospheres,

$$V = \sqrt{\frac{2z\ 10{,}334\ n}{S}}$$

If H = the height due the pressure, and if W = the weight of the water in the instru-

The history of the injector may be stated in few words.

The principle of the *entrainement*, by a current of one fluid issuing under pressure from an orifice, of the fluid surrounding the vessel was known as early as 1870 by Philibert de Lorme. It was applied to the locomotive blast-pipe more than a half century ago. Gurney, forty years ago, used the steam-jet as a ventilator; Nagel & Kaemp, Thomson, and others afterward employed it in engineering practice.

Giffard finally applied it, in combination with the principle already explained by the writer, to the introduction of feed-water into the steam-boiler.

Del Peche, Koch, Schaeffer & Budenburg, and Messrs. Dreyer, Rosenkranz & Droop, all produced modifications of the instrument.

Krauss, Körting, Schau, and Friedmann brought out auxiliary details, or simplified the injector for the purpose of reducing first cost and liability to derangement.

The most beautiful and ingenious modifications, looking to economy of steam and quantity of discharge, were made in the United States.

Messrs. Sellers & Co. secured the right to manufacture, and by careful and intelligent efforts soon increased the delivery to nearly double that given by the instrument of Giffard. They reduced its weight and cost, improved its details, and attained a comparatively high efficiency. They finally introduced their self-adjusting injector, in which the water-supply is regulated automatically by the action of the overflow, its suction increasing the area of the annulus through which the water enters, and its pressure, when the supply is in excess, throwing back the exterior nozzle, which is made movable, and reducing the supply.

The Mack, the Rue, and other forms recently introduced in the United States are Giffard injectors, having fewer moving parts. They are less costly, and less liable to derangement by bad water, but are usually much less readily adapted to a wide range of supply.

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ment per cubic meter, usually about 500 kilograms, as the expenditure of energy in propulsion and resistance are the same,

$$V = \sqrt{2 z H}$$

In view of the fact that in actual practice the density is not that assumed, Giffard proposes the formula,

$$V = \sqrt{2 z k \frac{10{,}334 n}{1{,}000}}$$

in which k is a co-efficient to be determined, and usually varying between 2 and 2.25.

Again—

$$p = a V d$$

and—

$$P + p = a v W$$

In determining temperature of feed, according to Regnault, the loss in passing from the temperature T to the temperature t is

$$H = p\,(606.5 + 0.305^{*}\,T - t) = P\,(t - t')$$

where t' = is the temperature of feed-water before entering.

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[*] Recent experiments seem to indicate this co-efficient to be slightly less than given by Regnault.—R. H. T.

Morton, of Glasgow, has applied the injector on a larger scale as an air-pump and condenser for steam-engines. In the United States, Mr. H. W. Bulkley and Mr. Ransome have introduced condensers, in which the stream of condensing water is made by the adoption of a similar law to act the part of the air-pump.

KORTING'S STEAM-JET is illustrated in the accompanying sketch, (Fig. 73,) as it was exhibited in this class of apparatus at Vienna, with a number of modifications adapted to use as "ejector-condensers," injectors, bilge and ashes pumps, and other such applications.

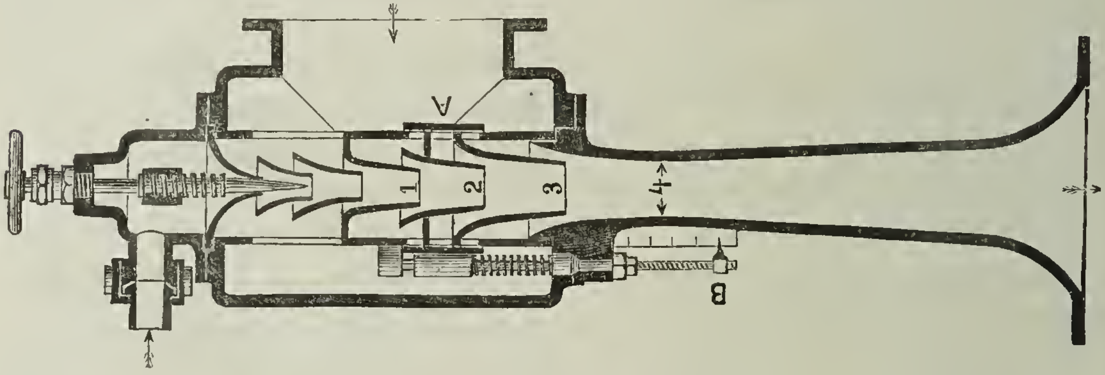

FIG. 73.—E. Korting's steam-jet.

In this instrument* the sliding collar A and cones 1, 2, and 3 are adjustable in relative position by the screw B, which is set at the exact point required for maximum efficiency by means of a scale and pointer. The steam enters at the small nozzle seen at the upper right-hand corner of the figure, and is admitted into the cones by the use of the hand-wheel shown. The air-current enters from below, passes between the cones at A, and emerges as shown by the arrow on the left. The same disposition to which the efficiency of the Friedmann injector is attributed gives effectiveness here. The adjustment of A permits the use of one or more openings between the cones, and determines the capacity of the instrument while working. This form of jet is used as a gas-exhauster.

151. THE PRINCIPLES OF STEAM-BOILER CONSTRUCTION are exceedingly simple, and although attempts are almost daily made to obtain improved results by varying the design and arrangement of heating-surface, the best boilers of nearly all makers of acknowledged standing are practically equal in merit, although of very diverse forms.

In making boilers the effort of the engineer should evidently be:

1st. To secure complete combustion of the fuel without permitting dilution of the products of combustion by excess of air.

2d. To secure as high temperature of furnace as possible.

3d. To so arrange heating-surfaces that, without checking draught, the available heat shall be most completely taken up and utilized.

4th. To make the form of boiler such that it shall be constructed without mechanical difficulty or excessive expense.

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* Lately introduced into the United States by Messrs. Schütte & Goehring, of Philadelphia.

5th. To give it such form that it shall be durable, under the action of the hot gases and of the corroding elements of the atmosphere.

6th. To make every part accessible for cleaning and repairs.

7th. To make every part as nearly as possible uniform in strength and in liability to loss of strength by wear and tear, so that the boiler when old shall not be rendered useless by local defects.

8th. To adopt a reasonably high "factor of safety" in proportioning parts.

9th. To provide efficient safety-valves, steam-gauges, and other appurtenances.

10th. To secure intelligent and very careful management.

In securing complete combustion, the first of these desiderata, an ample supply of air and its thorough intermixture with the combustible elements of the fuel are essential; for the second, high temperature of furnace, it is necessary that the air-supply shall not be in excess of that absolutely needed to give complete combustion. The efficiency of a furnace is measured by

$$E = \frac{T - T'}{T - t}$$

in which E represents the ratio of heat utilized to the whole calorific value of the fuel; T is the furnace-temperature; T′ the temperature of the chimney, and t that of the external air. Hence the higher the furnace-temperature and the lower that of the chimney, the greater the proportion of available heat.

It is further evident that, however perfect the combustion, no heat can be utilized if either the temperature of chimney approximates to that of the furnace, or if the temperature of the furnace is reduced by dilution approximately to that of the chimney. Concentration of heat in the furnace is secured, in some cases, by special expedients, as by heating the entering air, or as in the Siemens gas furnace, heating both the combustible gases and the supporter of combustion. Detached fire-brick furnaces have an advantage over the "fire-boxes" of steam-boilers in their higher temperature; surrounding the fire with non-conducting and highly-heated surfaces is an effective method of securing high furnace-temperature.

In arranging heating-surface, the effort should be to impede the draught as little as possible, and so to place them that the circulation of water within the boiler should be free and rapid at every part reached by the hot gases.

The directions of circulation of water on the one side and of gas on the other side the sheet should, whenever possible, be opposite. The cold water should enter where the cooled gases leave, and the steam should be taken off farthest from that point. The temperature of chimney-gases has thus been reduced by actual experiment to less than 300° Fahr., and an efficiency equal to 0.75 to 0.80 the theoretical is attainable.

The extent of heating-surface simply, in all of the best forms of boiler, determines the efficiency, and the disposition of that surface seldom affects it to any great extent. The area of heating-surface may also be varied within very wide limits without greatly modifying efficiency. A ratio of 25 to 1 in flue and 30 to 1 in tubular boilers represents the relative area of heating and grate surfaces in the practice of the best-known builders.

The material of the boiler should be tough and ductile iron, or, better, a soft steel containing only sufficient carbon to insure melting in the crucible or on the hearth of the melting-furnace, and so little that no danger may exist of hardening and cracking under the action of sudden and great changes of temperature.

Where iron is used it is necessary to select a somewhat hard, but homogeneous and tough quality for the fire-box sheets or any part exposed to flames.

The factor of safety is invariably too low in this country, and is never too high in Europe. Foreign builders are more careful in this matter than our makers in the United States. The boiler should be built strong enough to bear a pressure at least six times the proposed working-pressure; as the boiler grows weak with age, it should be occasionally tested to a pressure far above the working-pressure, which latter should be reduced gradually to keep within the bounds of safety. In the United States, the factor of safety is seldom more than four in the new boilers, frequently much less, and even this is reduced practically to one and a third by the operation of our inspection-laws.

CHAPTER VII.

AIR AND GAS ENGINES.

Steam compared with gas as a motor; Comparison of steam and gas engines; The hot-air engine; Its disadvantages; Ericsson's engine; Stirling and Cayley's engines; Henderson's theory of the aero-steam engine; Calculation of its efficiency; Examples; Lehman's hot-air engine; The Brayton gas-engine; Trial of the Brayton engine; Results; Detailed description of the Brayton engine; Conclusions from results of trial; Advantages of non-explosive gas-engines; The Otto & Langen gas-engine; Trial by Mon. H. Tresca; Results of trial; Cause of the exceptional economy observed; Rankine's theory of gas-engines.

152. Steam compared with air as a motor.—Air and gas engines are expected by many engineers to compete, ultimately, with the steam-engine as economical, if not otherwise highly efficient, motors.

The actual standing of the best steam-engine of the present time, as an efficient heat-engine, is really very high. The sources of loss are principally quite apart from the principles of design and construction, and even from the operation of the machine, and it may be readily shown* that, to secure any really important advance toward theoretical efficiency, a radical change of our methods must be adopted, and probably that we must throw aside the heat-engine in all its forms, and substitute for it some other apparatus by which we may utilize some mode of motion and of natural energy other than heat.

The mechanical equivalent of heat is reckoned at 772 foot-pounds per thermal unit, that unit being the quantity of heat necessary to raise one pound of water one degree in temperature.

A pound of pure carbon yields, in burning, 14,500 units of heat, equivalent to $14{,}500 \times 772 = 11{,}194{,}000$ foot-pounds of energy. A pound of good coal containing 91 per cent. carbon, as shown in the report of the committee of the American Institute testing steam-boilers in 1871, produces about 13,200 units of heat, and its mechanical equivalent is $13{,}200 \times 772 = 10{,}190{,}400$ foot-pounds of work.

The very best classes of modern steam-engines very seldom consume less than two pounds of coal per horse-power per hour, and it is a good engine that works regularly on three pounds. A horse-power raises 1,980,000 pounds one foot high per hour, consequently a pound of coal, in our very best engines, develops but $\frac{1980000}{2} = 990{,}000$ foot-pounds, instead of the 10,190,400 which it would give us were there no loss of power.

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* See Scientific American, vol. xxviii; No. 2; p. 16.

The first-class steam-engine, therefore, yields less than 10 per cent. of the work stored up in good fuel, and the average engine probably utilizes less than 5 per cent.

A part of this loss is unavoidable, being due to natural conditions beyond the control of human power, while another portion is, to a considerable extent, controllable by the engineer or by the engine-driver.

Scientific research has shown that the proportion of heat stored up in any fluid, which may be utilized by perfect mechanism, must be represented by a fraction, the numerator of which is the range of temperature of the fluid while doing useful work, and the denominator of which is the temperature of the fluid when entering the machine, measured from the "absolute zero"—the point at which heat-motion is supposed to cease entirely—461°.2 Fahr. below the zero of the common scale.

Thus, steam, at a temperature of 320° Fahr., being taken into a perfect steam-engine, and doing work there until it is thrown into the condenser at 100° Fahr., would yield $\frac{320-100}{320+461}=0.28+$, or rather more than one fourth of the 10,190,400 foot-pounds of work which it should have received from each pound of fuel.

The ratio, $\frac{990.000}{2849842}=0.34=\frac{1}{3}$, of the work done by our best class of engines, to this possible performance of a perfect engine using 75 pounds of steam, shows us how much we have to hope for in improving the steam-engine.

The proportion of work that a non-condensing but otherwise perfect engine, using steam of 75 pounds pressure, could utilize would be $\frac{320-212}{320+461}=0.14=\frac{1}{7}$; and, while the perfect condensing-engine would consume two-thirds of a pound of good coal per hour, the perfect non-condensing engine would use $1\frac{1}{3}$ pounds per hour for each horse-power developed, the steam being taken into the engine and exhausted at the temperatures assumed above. Also, were it possible to work steam down to the absolute zero of temperature, the perfect engine would require but 0.19 pound of similar fuel.

It may therefore be stated, with a close approximation to exactness, that of all the heat derived from the fuel about seven-tenths is lost through the existence of natural conditions over which man can probably never expect to obtain control, two-tenths are lost through imperfections in our apparatus, and only one-tenth is utilized in even good engines.

Boiler and engine are intended to be included when writing of the steam-engine above. In this combination, a waste of probably three-tenths at least of the heat derived from the fuel takes place in the boiler and steam-pipes, on the average, in the best of practice, and we are therefore only able to anticipate a possible saving of $0.2\times0.75=0.15$, about one-sixth of the fuel now expended in our best class of engines, by improvements in he machine itself.

The best steam-engine, apart from its boiler, therefore, has 0.85, about ive-sixths, of the efficiency of a perfect engine, and the remaining sixth s lost through waste of heat by radiation and conduction externally, by condensation within the cylinder, and by friction and other useless work done within itself. It is to improvement in these points that inventors must turn their attention if they would improve upon the best modern practice by changes in the construction of the steam-engine.

To attain further economy, after having perfected the machine in these particulars, they must contrive to use a fluid which they may work through a wider range of temperature, as has been attempted in air-engines by raising the upper limit of temperature, and in binary vapor engines by reaching toward a lower limit, or by working a fluid from a higher temperature than is now done down to the lowest possible temperature. The upper limit is fixed by the heat-resisting power of our materials of construction, and the lower by the mean temperature of objects on the surface of earth, being much lower at some seasons than at others.

In the boiler the endeavor must be made to take up all the heat of combustion, sending the gases into the chimney at as low a temperature as possible, and securing in the furnace perfect combustion without excess of air-supply.

The best engines still lack 15 per cent. of perfection, and the best boilers, as an average, over 30 per cent.

The hot-air engine seems to be the most promising of known expedients for increasing economy by widening this range of temperature, and among hot-air engines the furnace gas-engine would seem most probably the form of highest efficiency.

153. STEAM AND GAS ENGINES COMPARED.—Yet, for medium and high powers, the steam-engine stands to-day, as it has stood from the time of Watt, without a rival as a prime mover. The high pressure which can be obtained by the evaporation of water without excessively high temperature, the compactness of the machine itself, and incidental advantages, place it beyond comparison in advance of all other heat-engines for powers exceeding, at the highest, two or three horse-power in ordinary cases.

For extremely small powers, however, the necessity of having a skilled attendant makes the steam-engine too expensive where, as with small powers, the cost of attendance becomes a large proportion of the total running expense. The difficulty of finding a proper location for the steam-engine and its boiler; the danger which must always attend, in a greater or less degree, its use; the first cost of so complicated and nice a piece of apparatus; the expense of repairs, and other less apparent objections, seriously interfere with its introduction and general use. A "domestic motor," as this class of machine here considered is frequently called, should, so far as possible, be perfectly safe, healthful, inexpensive in first cost and in maintenance, compact, cleanly, and durable, and should not require specially-trained attendants.

Such a prime mover has not yet been produced; but the hot-air, electric, and gas engines are finding their way into use gradually in some such situations as are here referred to, and are becoming of some importance even as compared with the steam-engine. Some examples of these machines were shown at Vienna, although not representing the best of that practice with which our own mechanics are already familiar.

154. **The hot-air engine** has been long known, and many varieties exist. The readiness with which its working-fluid is obtained from the surrounding atmosphere, its efficiency as a heat-engine, its manageableness, and its safety from danger of explosion at high temperatures, have made this a favorite field with inventors. The greatest difficulty met is that of rapidly transferring heat to and from the mass of air employed—a consequence of its nearly perfect non-conduction—and that of using a much larger cylinder with the low pressures at which it is worked than is found necessary where, as in the steam-engine, high pressure is attainable. The theoretic efficiency of this form of heat-engine is very great, in consequence of its wide range of temperature; and it is also practically quite high. A perfect air-engine working between temperatures of 650° and 150° F., would have an efficiency of 0.45 when expanding twice. It would have a mean pressure of 8.33 pounds per square inch, and would require a large volume of working-cylinder—$\frac{27\frac{1}{2}}{S}$ cubic feet per horse-power where S = the number of strokes per minute.

155. **The Ericsson engine.**—The form of air-engine most familiar to American engineers is the Ericsson so-called "caloric" engine, in which the change of temperature occurs at an approximately constant pressure. It consists of a working-cylinder, placed above a furnace, and containing a piston which works within the upper portion. The piston is protected from the direct heat of the furnace by a non-conducting mass suspended from its lower side.

Air is compressed in a compressing-pump, and is forced through a check-valve into a receiver, where it remains under pressure until it passes into the working-cylinder. *En route* to the working-cylinder, it passes through a regenerator—a vessel filled with wire-gauze, or some other metallic porous mass—which has been heated by the exhaustion through it of air which has done duty in the cylinder. Reaching the lower part of the working-cylinder, it is in direct contact with the furnace, and is rapidly heated by convection. Expanding, it forces up the piston, and on the return-stroke is exhausted through the regenerator, where it leaves a portion of its heat to be transferred again to the next entering charge of air.

The air-engines of the steamer Ericsson, by far the largest ever constructed, were found by Professor Norton to consume 1.87 pounds of coal per horse-power per hour, and gave an efficiency equal to 0.10.

156. STIRLING'S ENGINE.—In another form of engine, invented by Dr. Robert Stirling in 1827, the temperature of air changes under approximately constant volumes, the same mass of air being sent alternately into and out from the heater, its change of pressure producing the movement of the piston in the working-cylinder. Such an engine, working between the limits of temperature already above assumed, gives an efficiency of 0.3, with a mean pressure of $37\frac{3}{4}$ pounds per square inch, consuming about $1\frac{2}{3}$ pounds of coal per horse-power per hour.

157. CAYLEY'S ENGINE.—A later form of air-engine, and one which promises well in the opinion of some able engineers, is the furnace-gas engine, in which the furnace-gases and products of combustion pass into the working-cylinder and are utilized as the working-fluid. The earliest engine of this class was that of Sir George Cayley, invented about 1830. A well-known example of this type is that of the American engineer Stephen Wilcox. The difficulties met with in this engine are the burning-out of the piston and working-cylinder under the intense heat, and the "cutting" of surfaces by the dust carried over in the working-fluid. The former difficulty has been at least partially overcome by the use of a water-jacket. The latter will very possibly be avoided by the use of a combustible which, like the petroleums, contains no gritty constituent.

158. THE AERO-STEAM ENGINE is a modification of the furnace-gas engine, in which the working-fluid is a mixture of the furnace-gases with steam from a steam-boiler within which the fuel is burned; it has recently excited much attention from engineers. This engine was experimentally fitted to the steamer Novelty, in the United States, many years ago, and has since been brought into notice by several inventors, among the latest of whom is Mr. Warsop, a British engineer.

The theory of this engine is similar to that of other air and gas engines in many respects, and has been given by Mr. J. Augustus Henderson, in a graduating thesis at the Stevens Institute of Technology.

His method and results are as follows:

THE THEORY OF AERO-STEAM ENGINES.—The case to be discussed is restricted to that of a high-pressure aero-steam boiler and engine of the following general description:

The boiler would be provided with an inclosed furnace, from which the whole products of combustion under pressure would be injected into the water, and there so lowered in temperature, at the expense of further formation of steam, that when thoroughly mixed with all of the steam formed, a given final temperature of superheating would be produced. The engine would consist essentially of a main working-cylinder using this mixture expansively to atmospheric pressure, an air-compressing pump to supply air to the imprisoned fuel under the boiler-pressure, and of the mechanism by which the two would be connected and the excess of work delivered.

Before making any numerical calculations, the general formula applicable to such an engine and boiler are introduced as embracing the main points of importance or of interest, and as serving for a common basis from which the several examples may be worked out by direct substitution. The principal authority referred to for the constants used in calculation was Professor Rankine, and his nomenclature and fundamental equations were applied when practicable. The majority of the formula, however, and more especially those relating to the determination of the proportion of steam and air by weight, and by volume before mixture, their tension when mixed, and to the determination of the value of the constant γ for the mixture, are here deduced, as no such formula could be found in published works. All of the formulas, other than those whose results are ratios, apply to such quantities as are produced by the entrance of one pound of air through the compressing-pump, this mode of treatment greatly simplifying the relations between them. The general method adopted for obtaining the effective work developed per pound of air admitted, by computing the work of expansion and compression from the theoretic forms of the diagrams, and taking the difference, was found to be the most satisfactory and direct under the circumstances. It should be observed that the word *air*, owing to its shortness, is commonly employed to denote the *products of combustion*, except, of course, in those statements where the use of the more specific term becomes necessary.

Below is given the general notation to be used in the formulas:

Pressures, measured absolutely in pounds per square foot:

P_a = pressure of atmosphere.

p_1 = pressure in boiler and during admission in main cylinder.

p_2 = pressure of exhaust = P_a when back pressure above atmosphere is not considered.

P_a, P_1, &c., the same measured in pounds per square inch, and above the atmosphere, except when otherwise stated.

Temperatures, in degrees Fahrenheit:

t_a = temperature of atmosphere.

t_b = temperature after compression in pump.

t_c = temperature upon leaving the fire.

t_1 = temperature of mixed air and steam.

t_2 = temperature of exhaust.

t_f = temperature at which feed-water is supplied.

τ_a, τ_b, &c., the same as measured from the absolute zero — 461·2° F.

Weights in pounds per pound of air admitted:

w_c = weight of products of combustion.

w_s = weight of steam formed.

w = weight of mixture of the two.

Volumes in cubic feet per pound of air admitted:

v_a = volume of one pound air when first admitted to compressing-pump.

v_b = volume of the same when compressed.

v_c = volume of products of combustion at temperature of mixture.

v_s = volume of steam at the same temperature.

v_1 = volume of air and steam after mixture.

v_2 = volume of mixture when expanded to atmospheric pressure.

Ratios:

r = ratio of expansion in main cylinder.

r_c = ratio of compression in pump.

r_p = ratio of boiler to atmospheric pressure.

q_w = ratio of weight of steam to products of combustion.

q_v = ratio of volume of steam to products of combustion.

q_h = ratio of heat absorbed by steam to that remaining in air *above heat of compression*.

The quantities usually assumed as *data* are P_a, P_1 and P_2, t_a, t_1 and t_f, from which p_a, p_1, p_2, and r_p, τ_a and τ_1 may be directly found; also H the total heat of combustion in foot-pounds, per pound of fuel, and N the number of pounds of air supplied for the same.

The points to be determined are taken up in the order in which they naturally present themselves, beginning with the *heat of compression and ratio of compression in pump.*

Since the air is compressed without gain or loss of heat,

$$\frac{\tau_b}{\tau_a} = \left(\frac{p_1}{p_a}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$$

and

$$\frac{r_a}{r_b} = \left(\frac{p_1}{p_a}\right)^{\frac{1}{\gamma}} = r_p^{\frac{1}{\gamma}}$$

where $\gamma = 1.408$ for air. From these two equations it follows that

$$\tau_b = \tau_a\, r_p^{\frac{\gamma-1}{\gamma}} \quad \text{and} \quad r_c = r_p^{\frac{1}{\gamma}}$$

in which substituting the value of γ, and adapting to the use of logarithms, we get

$$\log \tau_b = \log \tau_a + 0.29 \log r_p \ldots\ldots (1)$$
$$\log r_c = 0.71 \log r_p \ldots\ldots (2)$$

from which t_b and r_c may be computed.

Initial temperature t_c of gases leaving fire.—In finding this, t_h, the temperature directly added by combustion, is first obtained by the formula

$$t_h = \frac{H}{772\,(1+N) \times 0.238} \ldots\ldots (3)$$

the numbers 772 and 0.238, being Joule's equivalent and the specific heat of the products of combustion under constant pressure.

This temperature being added to that of the air leaving the pump, gives

$$t_c = t_b + t_h \ldots\ldots (4)$$

Ratio of heat of combustion absorbed in gasifying steam, to that remaining in air, above heat of compression.—On account of the transfer of heat in the boiler taking place at constant pressure, the quantities of heat are proportional to the changes in temperature, as is seen in the equation giving the desired ratio,

$$q_h = \frac{0.238\, w_c\,(t_c - t)}{0.238\, w_c\,(t_1 - t_b)} = \frac{t_c - t_1}{t_1 - t_b} \ldots\ldots (5)$$

The percentage of heat entering steam and air might, if necessary, be obtained from the formulas

$$h_s = \frac{100\quad q_h}{1 \times q_h} \quad \text{and} \quad h_c = 100 - h_s.$$

Weight of products of combustion per pound of air admitted.

$$w_c = \frac{1+N}{N} \ldots\ldots (6)$$

Proportions by weight of steam and air.

Since the steam is to be in such quantity that the heat required to form it in the gaseous state at $t_1°$ from the feed-water shall leave the air at the same temperature, and since the heat lost by the air is wholly taken up by the steam, we must have

$$0.238\, w_c\,(t_c - t_1) = w_s \times h$$

where h is equal to the total heat of gasification per pound of steam for any constant pressure, and has the empirically determined value of

$$1092 + 0.475\,(t_1 - 32) - (t_1 - 32)$$

thermal units. By substituting this in the previous equation and reducing, is obtained the following:

$$q = \frac{w_s}{w_c} = \frac{0.238\ (t_c - t_1)}{1124 + 0.475\ (t_1 - 32) - t_f} \cdots\cdots (7)$$

$$\therefore \qquad w_s = w \times q_w \cdots\cdots (8)$$

$$\text{and} \qquad w_1 = w_c + w_s = w_c\ (1 + q_w) \cdots\cdots (9)$$

Proportion by volume of steam and air.

For one pound of any gas we must have

$$\frac{p\ v}{\tau} = \frac{p_o\ v_o}{\tau_c} \text{ or } v = \frac{p_o\ v_o}{\tau_o} \times \frac{\tau}{p}$$

in which $\frac{p_o\ v_o}{\tau_o}$ is constant, and has for its value the difference between the dynamical specific heats under constant pressure and under constant volume of the gas considered.

For air, $\frac{p_o\ v_o}{\tau_o}$ is equal to 53.15, and for steam 85.00 foot-pounds.

Since the volume of the products of combustion is known to be almost exactly the same as that of the air supplied, for the same pressure and temperature, in the present case v_c will be the volume of one pound of air at the pressure and temperature of superheating, or

$$v_s = 53.15 \frac{\tau_1}{p_1} \cdots\cdots (10)$$

The volume of the steam will be that of a weight, w_s, at the same pressure and temperature, or

$$v_s = 85 \frac{\tau_1}{p_1} \times w_s \cdots\cdots (11)$$

From v_s and v_c are directly obtained

$$q_v = \frac{v_s}{v_c} \cdots\cdots (12)$$

$$\text{and} \qquad v_1 = v_c + v_s \cdots\cdots (13)$$

Here, v_s, v and q_v, of course apply only to the volumes before mixture, as after mixture v_s and v_c each equal v_1 and $q_v = 1$. This diffusion of the air and steam to the same volume v_1, is accompanied by a corresponding fall in tension of each, but the sum of the two tensions remains equal to the pressure p_1 before mixture, and neither the resultant pressure, volume, nor temperature is affected.

Determination of the value of γ, proper for mixed air and steam.

The general equation of adiabatic curves for any gas is

$$p = \text{constant} \times v^{-\gamma}$$

where γ is constant, and has for its value the ratio of the specific heat at constant pressure, to that at constant volume, of the gas under consideration.

Denoting by C^p_a and C^v_a, C^p_s and C^v_s, the specific heats at constant pressure and constant volume of air and steam, respectively, we thus have

$$\text{for air} \qquad \gamma_a = \frac{C^p_a}{C^v_a} = \frac{0.238}{0.169} = 1.408$$

$$\text{and for steam} \qquad \gamma_s = \frac{C_s}{C^v_s} = \frac{0.480}{0.370} = 1.3$$

very nearly.

It should be mentioned that the specific heats of the products of combustion of all ordinary fuels are stated by Rankine not to differ sensibly from those of pure air, and accordingly no distinction is here made.

To find γ_m, the value proper for air and steam mixed in the proportions already found, we may determine the two specific heats C^p_m and C^v_m the mixture, and take their ratio.

As the weights w_s and w_c bear to each other the ratio q_w, and have w_1 for their sum,

$$C^p_m = \frac{(C^p_a + q_w C^p_s)\, w_c,}{w_1} \quad \text{and} \quad C^v_m = \frac{(C^v_a + q_w C^v_s)\, w_c,}{w_1}$$

$$\therefore \gamma_m \frac{C^p_m}{C^v_m} = \frac{(C^p_a + q_w C^p_s)\ w_c}{w_1} \times \frac{w_1}{(C^v_a + q_w C^v_s)\ w_c} = \frac{(C^p_a + q_w C^p_s}{(C^v_a + q_w C^v_s}$$

in which, substituting the values of the several specific heats,

$$\gamma_m = \frac{0.238 + 0.48\ q_w}{1.169 + 0.37\ g_w} \quad \text{(14)}$$

To use γ_m as thus calculated, it is necessary that the mixture be sufficiently superheated above the point of saturation of the steam, to keep the latter in the truly gaseous state, a condition that would probably be realized in most actual examples.

Ratio of expansion in main cylinder and temperature of exhaust.

It is here assumed, owing to the insulation action of the air in mixture, and to the cylinders being properly clothed to prevent conduction and radiation, that no appreciable quantity of heat is lost, and consequently that the curve of expansion will be ruly adiabatic, in which case, analogous to that of the compressing-pump,

$$\tau_2 = \tau_1 \left(\frac{p_2}{p_1}\right)^{\frac{\gamma_m - 1}{\gamma_m}} \quad \text{and} \quad r = \left(\frac{p_1}{p_2}\right)^{\frac{1}{\gamma_m}}$$

or taking the atmospheric pressure for p_2, since $\frac{p_2}{p_1}$ reduces to $\frac{p_a}{p_1} = r_p - 1$,

$$\tau_2 = \tau_1\, r_p^{-\frac{\gamma_m - 1}{\gamma_m}}, \quad \text{and} \quad r = r^{\frac{1}{\gamma_m}};$$

from which follow:

$$\log \tau_2 = \log\ \tau_1 + \frac{\gamma_m - 1}{\gamma}\ [\text{a. c. } \log\ r_p] \quad [15]$$

and

$$\log r = \frac{1}{\gamma_m}\ \log\ r_p \quad [16]$$

Volumes of main and pump cylinders per pound of air admitted.

Main cylinder, $v_2 = r\ v_1$ .... [17]

Pump-cylinder, $v_a = 53.15\, \frac{\tau_a}{p_a}$ .... [18]

Ratio in which the space swept by the pump-piston is less than that swept by main piston.

$$q_c = \frac{v_a}{v_2} \quad [19]$$

Mean forward absolute pressures on main and pump pistons.

In the main cylinder, where the curve of expansion has for its equation

$$p = \text{constant} \times v^{-\gamma_m}$$

it may be demonstrated by the integral calculus, according to the general method set forth in Rankine, that q_m, the ratio of the mean forward pressure p_m to the initial pressure p_1, is given by the formula—

$$q_m = \frac{p_m}{p_1} = \frac{\gamma_m\, r^{1} - r^{-\gamma_m}}{\gamma_m - 1} = \frac{\frac{\gamma_m}{r} - \frac{1}{r_q}}{\gamma_m - 1} \quad [20]$$

from which

$$p_m = q_m p \quad\ldots\ldots\ldots\ldots [21]$$

For the pump, denoting the ratio by q_n, and the mean pressure by p_n, we have in a similar manner,

$$q_n = \frac{p_n}{p_1} = \frac{\overset{\gamma_a - 1}{\overline{r_c \qquad r_p}}}{\gamma_a - 1} \quad\ldots\ldots\ldots\ldots [22]$$

and

$$p_n = q_n p_1 \quad\ldots\ldots\ldots\ldots [23]$$

Gross work in main cylinder.

$$U_m = (p_m - p_a) \times v_2 \quad\ldots\ldots\ldots\ldots [24]$$

Work of resistance of pump.

$$U_n = (p_n - p_a) \times v_a \quad\ldots\ldots\ldots\ldots [25]$$

Effective work developed, per pound of air admitted.

$$U_e = U_m - U_n \quad\ldots\ldots\ldots\ldots [26]$$

Heat of combustion used for the same, in foot-pounds.

$$H_1 = \frac{H}{N} \quad\ldots\ldots\ldots\ldots [27]$$

Heat rejected in exhaust, in foot-pounds.

$$H_2 = H^1 - U_e \quad\ldots\ldots\ldots\ldots [28]$$

Mean effective pressure, or pressure in main cylinder, equivalent to performance of work.

$$P_e = \frac{U_e}{V_2} \quad\ldots\ldots\ldots\ldots [29]$$

When given in pounds per square foot, as directly computed from this formula, P_e further represents the effective energy developed per cubic foot swept through by the main piston.

Pressure equivalent to expenditure of heat.

$$P_h = \frac{H_1}{V_2} \quad\ldots\ldots\ldots\ldots (30)$$

Efficiency of fluid.

$$E = \frac{U_e}{H_1} = \frac{P_e}{P_h} \quad\ldots\ldots\ldots\ldots (31)$$

This also includes the efficiency of the furnace, which for the given form of boiler is unity, because of there being no waste heat up the chimney.

Weight of fuel used, per effective horse-power per hour.

Since the work performed per pound of fuel is N × U_e, and there are 1,980,000 feet pounds to be performed by the desired weight C of that fuel, it follows that

$$C = \frac{1{,}980{,}000.}{N \times U_e} = \frac{1{,}980{,}000}{E \times H.} \quad\ldots\ldots\ldots\ldots (32)$$

The numerical examples, six in number, are given in tabular form and in the order in which they were originally worked out, as being applicable to the plan of aero-steam engine considered, while working under several conditions, relative to the higher limiting pressures and temperatures, and with varying supplies of air, above the amount necessary for complete combustion. These quantities were chosen to fall within the limits of possible practice, and at the same time to give those results most likely to be applied with advantage to this form of engine.

In the first example given, the temperature t_2 of exhaust was chosen at 212° F. to make a more direct comparison with the common high-pressure steam-engine, and the boiler pressure p_1 afterward calculated, but in the other five it was found best to place p_1 among the data instead of t_2, the order of all the determinations remaining as in the general formulas.

The following data are common to all of the examples, and therefore are here introduced, to be referred to when needed.

Common data.

$P_a = P_2 = 14.7$ pounds per square inch, or $p_a = p_2 = 2{,}116.4$ pounds per square foot.

$H = 10{,}000{,}000$ foot-pounds, or somewhat less than 13,000 British thermal units, a fair value for good coal, whether bituminous or anthracite.

$t_a = 50^\circ$, being roughly assumed as about the average atmospheric temperature in this climate.

$t_f = 100^\circ$, a value that is supposed to be reached by the use of a feed-water heater attached to the exhaust of the engine.

The least quantity of air practically required for the complete combustion of one pound of average coal or coke was taken at 18 pounds, being about 1.5 times the amount theoretically necessary to furnish the oxygen for combination.

Following is given the table of examples, arranged as far as possible with reference to compactness. The horizontal row of figures on the top of the table refers to the example, and the vertical one on the left to the general formulas as is there indicated.

The numerical calculations are only carried out so far as to prevent any practically considerable errors from arising. For ratios having values near unity, three places of decimals is considered to be amply sufficient.

The value of q_h in the third and fifth examples is caused to come out negative by the fact of t_b exceeding t_1 in which case it should be defined as the ratio of the combined quantities of heat supplied to the steam, both from the fire and the excess of heat of compression, to this latter excess, lost from the air by its fall in temperature from t_b° to t_1°.

Table of numerical calculations on aero-steam engines.

	Number of formula.	Symbol for quantity.	Denomination of quantity.	Number of example.					
				1	2	3	4	5	6
Data.		P_1	Above atmosphere, pounds square-inch.	32.63	60.	100.	106.	100.	60.
		t_1	Degrees Fahr	450.	450.	450.	600.	450.	600.
		N	Pounds	19.	18.	18.	18.	54.	54.
Results per pound of air admitted.	1	t_b	Degrees	256.1	357.9	466.4	466.4	466.4	357.9
	2	r_c	Ratio	2.294	3.172	4.301	4.301	4.301	3.172
	3	t_h	Degrees	2864.5	2864.5	2864.5	2864.5	989.6	989.6
	4	t_c	Degrees	3120.6	3222.4	3330.9	3330.9	1456.0	1347.5
	5	q_h	Ratio	13.773	30.102	−175.7	20.440	−61.34	3.088
	6	w_c	Pounds	1.056	1.056	1.056	1.056	1.019	1.019
	7	q_w	Ratio	0.519	0.540	0.561	0.502	0.196	0.137
	8	w_s	Pounds	0.547	0.570	0.592	0.530	0.200	0.140
	9	w_1	Pounds	1.603	1.636	1.648	1.586	1.219	1.159
	10	v_c	Cubic feet	7.106	4.503	2.932	3.418	2.932	5.246
	11	v_s	Cubic feet	6.218	4.104	2.759	2.897	0.957	1.174
	12	q_v	Ratio	0.875	0.911	0.941	0.848	0.326	0.223
	13	v_1	Cubic feet	13.324	8.607	5.691	6.315	3.889	6.420
	14	γ_m	Ratio	1.349	1.348	1.347	1.349	1.375	1.383
	15	τ_2	Degrees	212.0	137.9	75.1	162.1	58.8	215.2
	16	r	Ratio	2.380	3.336	4.593	4.584	4.454	3.239
	17	v_2	Cubic feet	31.71	28.71	26.14	28.95	17.32	20.80
	18	v_a	Cubic feet	12.84	12.84	12.84	12.84	12.84	12.84
	19	q_c	Ratio	0.405	0.447	0.491	0.444	0.741	0.612
	20	q_m	Ratio	0.734	0.596	0.476	0.476	0.482	0.601
	21	p_m	Pounds square foot	5004.9	6410.8	1861.8	7861.8	7960.9	6464.6
	22	q^n	Ratio	0.732	0.606	0.488	0.488	0.488	0.606
	23	q_n	Pounds square foot	4989.3	6518.3	8060.0	8060.0	8060.0	6518.3
	24	U_m	Foot-pounds	91597.	123296.	150179.	166306.	101227.	90429.
	25	U_n	Foot-pounds	36888.	51516.	76310.	76310.	76310.	56516.
	26	U_e	Foot-pounds	54709.	66790.	73869.	89996.	24917.	33913.
	27	H_1	Foot-pounds	555555.	555555.	555555.	555555.	185185.	185185.
	28	H_2	Foot-pounds	500846.	488775.	481686.	465559.	160268.	151272.
	29	P_e	Absolute pres., lbs. sq. ft	1729.2	2326.0	2825.9	3109.1	1438.6	1630.6
	29	P_e	Absolute pres., lbs. sq. in	11.98	16.15	19.63	21.59	9.99	11.33
	30	P_h	Absolute pres., lbs. sq. ft	17520.	19350.	21253.	19192.8	10692.0	8904.4
	31	E	Ratio	0.098	0.120	0.133	0.162	0.135	0.183
	32	C	Pounds	2.011	1.647	1.489	1.222	1.471	1.082

In order to give a clearer idea of the precise mode of obtaining the results given in this table, the calculations in the case of example two are below indicated in full, as they were originally worked out by direct substitution of the data in the formulas.

EXAMPLE TWO.

Data.

$P_1 = 60$ pounds, $t_1 = 450^\circ$ and $N = 18$ pounds.

$\therefore\ p_1 = 144 \times 60 + 2116.4 = 10756.4$ pounds per square foot.

$$r\,p = \frac{10756.4}{2116.4} = 5.082 \text{ and } \tau_1 = 450 + 461.2 = 911.\,2^\circ$$

RESULTS.

$$\log\ \tau_b = \log\ 511.2 + 0.29 \log\ 5.082$$

$$\therefore\ \tau_b = 819.1 \text{ and } t_b = 357.9^\circ \tag{1}$$

$$\log\ r_c = 0.71 \log\ 5.082$$

$$\therefore\ r_c = 3.172 \tag{2}$$

$$t^h = \frac{10{,}000{,}000}{772\,(1+18) \times 0.238} = 2864.5^\circ \tag{3}$$

$$t^c = 2864.5 + 357.9 = 3222.4^\circ \tag{4}$$

$$q_b = \frac{3222.4 - 450}{450 - 357.9} = 30.102 \tag{5}$$

$$w_c = \frac{1+18}{18} = 1.056 \text{ pounds} \tag{6}$$

$$q_w = \frac{0.238\,(3222.4 - 450)}{1124 + 0.475 \times 418 - 100} = 0.540 \tag{7}$$

$$w_s = 0.540 \times 1.056 = 0.570 \text{ pounds} \tag{8}$$

$$w_1 = 0.570 + 1.056 = 1.626 \text{ pounds} \tag{9}$$

$$v_a = 53.15\ \frac{911.2}{10756.4} = 4.503 \text{ cubic feet} \tag{10}$$

$$v_s = 85\ \frac{911.2}{10756.4} \times 0.57 = 4.104 \text{ cubic feet} \tag{11}$$

$$q_v = \frac{4.104}{4.503} = 0.911 \tag{12}$$

$$v_1 = 4.503 + 4.104 = 8.607 \text{ cubic feet} \tag{13}$$

$$\gamma_m = \frac{0.238 + 0.48 \times 0.54}{0.169 + 0.37 \times 0.54} = 1.348 \tag{14}$$

$$\frac{1}{\gamma_m} = 0.731 \text{ and } \frac{\gamma_m - 1}{\gamma^m} = 0.258$$

$$\log\ \tau_2 = \log\ 911.2 + 0.258\ (\text{a. c. log. } 5.082)$$

$$\therefore\ \tau_2 = 599.1^\circ \quad \text{and} \quad t_2 = 137.9^\circ \tag{15}$$

$$\log r = 0.741 \log 5.082$$

$$r = 3.336 \tag{16}$$

$$v_2 = 3.336 \times 8.607 = 28.71 \text{ cubic feet.} \tag{17}$$

$$v_a = 53.15\ \frac{511.2}{2116.4} = 12.84 \text{ cubic feet} \tag{18}$$

$$q_c = \frac{12.84}{28.71} = 0.447 \tag{19}$$

$$q_m = \frac{\dfrac{1.348}{3.336} - \dfrac{1}{5.082}}{0.348} = 0.596 \tag{20}$$

$$p_m = 0.596 \times 10756.4 = 6410.8 \text{ pounds per square foot} \tag{21}$$

$$q_n = \frac{\dfrac{1.408}{3.172} - \dfrac{1}{5.082}}{0.408} = 0.606 \tag{22}$$

$$p_n = 0.606 \times 10756.4 = 6518.3 \text{ pounds per square foot} \quad \ldots\ldots (23)$$

$$U^m = (6410.8 - 2116.4)\ 28.71 = 123,296 \text{ foot-pounds} \quad \ldots\ldots (24)$$

$$U_n = (6518.3 - 2116.4)\ 12.84 = 56,516 \text{ foot-pounds} \quad \ldots\ldots (25)$$

$$U_e = 124296 - 56516 = 66,780 \text{ foot-pounds} \quad \ldots\ldots (26)$$

$$H_1 = \frac{10,000,000}{18} = 555,555 \text{ foot-pounds} \quad \ldots\ldots (27)$$

$$H_2 = 555,555 - 66,780 = 488,775 \text{ foot-pounds} \quad \ldots\ldots (28)$$

$$P_e = \frac{66,781}{28.71} = 2,326 \text{ pounds per square foot,}$$

or 16.15 pounds per square inch ……(29)

$$P_h = \frac{555,555}{28.71} = 19,350 \text{ pounds per square foot,}$$

or 134.4 pounds per square inch ……(30)

$$E = \frac{66781}{555,555} = 0.120 \quad \ldots\ldots (31)$$

$$C = \frac{1,980,000}{18 \times 66781} = 1.647 \text{ pounds} \quad \ldots\ldots (32)$$

It might be well to give an application of the last set of formulas upon condensation, to illustrate the manner of their use, though the results were not thought of sufficient importance to be tabulated.

$$q_d = \frac{0.540}{0.911} \times \frac{85}{53.15} = 0.98 \quad \ldots\ldots (33)$$

$$p_s = \frac{0.98}{1.98} \times 21164. = 1030.7 \text{ pounds per square foot,}$$

or 7.16 pounds per square inch ……(34)

The required value t_d corresponding to this absolute pressure, was found by reference to tables to be 177.84° Fahrenheit.

The only other example in which these calculations were made was the third, where $q_d = 0.954$, $p_s = 7.17$ pounds per square inch, and $t_d = 178.35°$, the departure from the results of the previous case being but slight.

It should be stated that almost all of the general formulas from which these examples were worked out are also applicable to aero-steam engines using any smaller proportions of air than the whole of the products of combustion; only those relating to the determination of the separate weights of the air and steam would have to be altered.

In addition to the formulas and examples thus far given, several other problems were investigated, whose general conclusions only need be referred to. The most important of them relate—

(1.) To the effect which would be had upon the work and efficiency of an aero-steam engine, were the air and steam conceived to expand in separate cylinders, their weights, initial pressures and temperatures, and final pressures, being the same as in the mixture; and

(2.) To the determination of the size of the lifting air-pump for a condensing-engine.

In regard to the second of these problems, enough has been already said while the practicability of using condensation was being considered.

As the result of the first, it may be stated that in calculations made with the data of several of the previous examples, the work developed by the separate expansion of the weight w_s of air and w_s of steam, from the common initial temperature t_1 and pressure p_1 to the atmospheric pressure p_2 was in every case the same as the work already found for the weight w_1 ($= w_c + w_s$) of the mixture, expanding with the same values of p_1 t_1 and p_2.

The following are the conclusions arrived at concerning the most advantageous use of mixed air and steam in the engine under discussion:

(1.) When t_1 is required to have a moderate value, so that the effects of heat need not be provided for, comparatively high values of P_1 with the least possible supply of air N, are the most advantageous as yielding the highest efficiency consistent with the given temperature, in addition to high mean effective pressures, with moderate size of pump. The case is well illustrated by the third example. When preparations are made for the use of high temperatures, two additional cases arise.

(2.) If at the same time with high efficiency a high mean effective pressure and small pump are desired to be retained, P_1 must remain at a high value and N be kept reduced as far as possible. This case is equivalent to the preceding one with an elevation of t_1, as in example four.

If the very highest efficiency be required at the expense of an increased bulkiness of the engine, P_1 may be reduced and N increased as was done in example six.

159. In order to impart more concise ideas as to the leading dimensions as well as gross consumption of fuel of aero-steam engines of this class, there may be here introduced with propriety a short application of the results of a few of these examples to as many cases of actual engines, while working according to their data and exerting different given amounts of power.

The best examples to illustrate are probably the third, fourth, and sixth, which have just been cited as being typical of the three courses open to advantageous change in the data:

(1.) A large single-cylinder marine engine, to exert 1,000 indicated horse-power, while making 50 revolutions per minute and working according to the data of example three;

(2.) A locomotive with two cylinders indicating a power of 200 horses and making 150 revolutions while fulfilling the conditions of example four; and

(3.) A small single-cylindered stationary engine, of 10 horse-power, running with a speed of 80 revolutions, as illustrative of example six.

The quantities to be determined are V_m and V_n, the respective volumes in cubic feet of the main and pump cylinders when both are double-acting, and C_1 and C_t the consumptions of coal by the engine in pounds per hour and tons per day, respectively.

Denoting by the symbols P and R, the number of horse-powers and rate of revolution per minute of the engine, and referring to the general formulas or examples, for the values of W_e, P_e, v_2, v_a, q_c and C, we may directly see that

$$V_m = \frac{33000\ P}{2R \times U_e} \times v_2 = \frac{33000\ P}{2\ R\ P_e} \text{ cubic feet} \dots\dots\dots\dots (a)$$

$$V_n = \frac{33000\ P}{2R \times U_e} \times v_a = q_c V_m \text{ cubic feet} \dots\dots\dots\dots (b$$

$$C = C \times P \text{ pounds} \dots\dots\dots\dots\dots\dots\dots\dots (c)$$

$$C_t = C \times P \times \frac{24}{2240} = \frac{3 \times C \times P}{280} \text{ tons} \dots\dots\dots\dots (p)$$

It should be noticed that the first common factor in the second members of both equations, (*a*) and (*b*,) is the number of pounds of air admitted to the engine for each stroke of the piston.

The table given embraces the application of these formulas to the three cases proposed, and includes besides their principal data and direct results of calculation, three additional columns of the equivalent dimensions of the main and pump cylinders, whose diameters d_m and d_n, and common stroke s, are expressed to the nearest inch.

TABLE OF APPLICATIONS OF EXAMPLES.

Case No.	Data of engine.			Data of corres. examp.			Results of prev. calculations.			Final results.						
	P	R	$\frac{s}{d_m}$	P_1	t_1	N	P_e	q_c	C	V_m	V_n	d_m	d_u	s	C_1	C_t
1	1000	50	1	100	450	18	2826	0.491	1.489	116.78	57.22	64	45	64	1489.	15.95
2	200	150	1.5	100	600	18	3109	0.444	1.222	3.538	1.571	17	11	26	244.4	2.62
3	10	80	3	60	600	54	1631	0.612	1.082	1.265	0.774	11	9	22	10.82	0.116

Both d_m and S were at once determined from V_m by assuming the ratio $\frac{s}{d_m}$, entered among the data in the table, while d_n was computed from V_n after having found S.

In the second case, that of the locomotive-engine, the calculated volumes and dimensions apply to one only of each of the two equal pairs of main and pump cylinders; the gross consumption of coal is that for the whole engine.

Where either the main cylinder or pump is to be single instead of double acting, in order to perform an equal amount of work at the same rate of revolution of the engine, its volumes obtained from this table must of course be doubled, or, if the ratio of the stroke to the diameter remains as before, these latter linear dimensions must be increased in the proportion of $\sqrt[3]{2}$ (= 1.26 nearly) to 1.

It will be observed by a comparison with the results of actual practice, that, in the aero-steam engines here illustrated, there are to a great extent combined both the economy in fuel of the furnace-gas-air engine and the compactness of the ordinary steam-engine. Boilers for such engines admit of being made much smaller than those required for steam-engines of the same power, not only because of the absence of waste chimney-heat, but also because of the greater facility for imparting heat to the steam by the direct injection of the products of combustion into the water.

The values of the resultant efficiencies of these aero-steam engines that can be practically obtained, will of course be less than those calculated by the formulas of this article, on account of the fact that the latter do not consider the efficiency of the mechanism together with such losses as are caused by external radiation of heat, back pressure, incompetent expansion, &c., but in well-constructed engines these losses may be so far reduced as not to seriously affect the efficiency—a conclusion that receives confirmation by the close approximation of the results of Professor Rankine's formulas on steam and air to the results of actual practice.

The large loss arising from condensation in the cylinders of common steam-engines, which is caused by the readiness with which wet steam imparts its heat to the cylinder-walls, is almost wholly prevented in the aero-steam engine. The prevention of such loss has been practically shown in Mr. Warsop's experiments to constitute one of the great advantages in the use of mixed air and steam. Regarding the condensation that is liable to occur in the latter part of the expansion of the mixture, even when there is no loss of heat whatever by external conduction, it may be further stated that in those cases where this liquefaction takes place at all, because of the initial temperature not being sufficiently high for the ratio of expansion, the liberation of latent heat would theoretically somewhat more than compensate the pressures and volumes of the mixture for the loss in weight of steam, and would thus cause the diagrams as calculated to be really a little smaller than the actual ones. The curve of expansion would be affected to a slight extent before the first actual condensation, as steam departs from the laws of a perfect gas before becoming saturated.

It may, at first sight, appear strange that the resultant efficiency is thus directly increased where this condensation occurs, but when it is remembered that the latter is brought about through an increase of the initial pressure of the mixture as compared with its initial temperature, and that such a change is advantageous to the efficiency, the fact may be fully accounted for.

This theory has been here presented at length, because it includes the theory of every modification of furnace-gas engine in use; and the attention which the subject is now receiving, and may be expected hereafter to receive, from engineers, as one of the most promising fields of exploration and invention, give it an importance to which its partial and restricted application, at the present time, is not at all commensurate.

The Ericsson hot-air engine was brought out by that distinguished engineer more than twenty years ago, and soon became quite well known in England and Germany, as well as in the United States. Wilcox's engine came into the market some ten years afterward. Mr. Shaw introduced his engine and obtained a considerable market for it a little later. This machine was exhibited at Paris in 1867, in successful competition with the Laubereau engine.

160. THE LEHMANN ENGINE.—At the Vienna Exhibition of 1873, this class of motors was represented by that of Lehmann, patented in 1869. In general appearance and the arrangement of its mechanism, it resembles somewhat the Ericsson engine. It has no regenerator. It is, however, a machine of the same class as that of Stirling, already described.

A brick furnace incloses about one-half of a long iron cylinder, the other portion of which is surrounded by a water-jacket. Within this cylinder moves another, which fits it so loosely as to permit air to flow freely past it, as it moves from one end to the other. The outside cylinder is closed at the furnace-end and has fitted at the other end a piston connected with a "vibrating lever" and crank-shaft, somewhat as in the Ericsson engine. The smaller cylinder has both ends closed, and acts simply as a displacing-piston. When the engine is in such a position that the inner cylinder is at the outer end and nearest the working piston, the air contained within the large cylinder is forced to the opposite end, and becomes heated by contact with the surfaces within the furnace. Expanding, it drives the working-piston to the limit of its throw, and at the same time is, by the movement of the displacing cylinder, driven back into the end of the working-cylinder nearest the piston, where the cold water-jacket absorbs its heat, and its contraction permits the piston to return unresisted. The air, flowing from the cold to the hot end of the cylinder, and *vice versa*, thus by transfer of heat expands and contracts, doing its work quite effectively. Regulation, unfortunately, is performed *by a brake*, the worst possible kind of regulation where economy is sought, since it simply converts excess of power into heat, and throws it away uselessly.

It is stated that during two years a hundred and thirty of these engines have been sold in Germany. No evidence was presented indicating its expenditure of fuel, or cost of maintenance or of repairs.

161. GAS-ENGINES, in which combustible gases are fired, and the products of combustion used as the working fluid, properly fall within the last-named class. They differ, usually, merely in the mode of combustion. Gas is introduced into the working-cylinder with the proper proportion of atmospheric air. The mixture being fixed, the resulting explosion develops gas under high pressure, and impels the piston. The working-cylinder and the furnace are, therefore, in this case, identical. The difficulties met in this class of engines are the same as with other furnace-gas engines, except that no trouble arises from the introduction of dust. The cost of gas is usually a more serious objection, and the high tem-

perature of the products of combustion gives more serious trouble than in the other form.

Two forms of gas-engine, constructed in Europe, were exhibited at Vienna—the Lenoir and that of Otto & Langen. The former was a French, the latter a German, invention.

The LENOIR GAS-ENGINE was the earliest brought into even limited use. It was patented in 1860, and several hundred have since been constructed. In that exhibited at Vienna, the gas was fired by means of the spark of the Rhumkorff induction-coil or "inductorium." The action of the machine is rendered quite smooth, in spite of the great fluctuation of working-pressure, by the use of a heavy fly-wheel. This engine did very good work, and was used for driving other machinery, apparently very satisfactorily. The general form of the engine was that of the ordinary horizontal direct-acting steam-engine. The cylinder was surrounded by a water-jacket to preserve the interior surface smooth and to prevent destruction of the lubricant. The induction of the mixed gases is produced by the movement of the working-piston, the engine thus acting as a pump during the early part of the stroke. The induction-valve next closes, the spark passes, firing the imprisoned gases, and the piston is impelled by a pressure which is at first very considerable, but which drops rapidly as the products of combustion cool by expansion, and as the steam, which forms a considerable proportion of the mass, condenses by contact with the cold sides of the cylinder.

162. *Defects of explosive gas-engines.*—This wide variation of pressure, and this loss by condensation, make a serious reduction of the efficiency of the gas-engine. In an American gas and air engine invented by Mr. C. P. Leavitt, and as constructed by him for the late W. F. Stearns, the second of these losses is avoided, with probably important economical results, by keeping the interior of the chambers in which expansion occurs at so high a temperature that condensation cannot take place.

The proportion of air and gas used are intended to be 13½ to 1; but it probably varies somewhat.

163. *Trial of the Lenoir engine.*—Referrring to the experiments of M. Tresca on the Lenoir engine, M. Claudel states:

"The velocity of the engine is variable.

"The failure to ignite a single charge will stop it.

"To start it, it is necessary to give it several revolutions by hand.

"Lubricant must be abundant and the amount of oil cannot be estimated at less than 0.5 kilogram (1.1 pound=1¼ pint) per day.

"To obtain the best effect, it is necessary to produce ignition before the complete closing of the valve."

A machine of $0^{m}.24$ (9.5 inches) diameter of cylinder was very nearly one horse-power.

The water circulating through the cylinder-jacket carried away 0.6 of the total heat of combustion.

These experiments were made several years ago, since which time, it is to be presumed, some increase of efficiency has been effected.

The HUGON GAS-ENGINE, in which the gases are fired by an ingeniously-arranged gas-jet, and in which the use of a voltaic battery, which is always an inconvenient and unsatisfactory attachment, is avoided, was not exhibited at Vienna.

164. The BRAYTON GAS-ENGINE (Fig. 74) was entered for exhibition in the United States section, but up to the time of the departure of the writer, at the close of the session of the juries, had not appeared. In some respects this is an important improvement upon the preceding forms, and the following description, written by the writer before leaving the United States, and after a brief but careful examination, indicates its construction and peculiarities. It is of interest also as giving an idea of the cost of fuel.

In construction this engine resembles the steam-engine, its cylinder and piston, its valves, and its connections being essentially similar. The principal difference consists in the addition of a compressing-pump and a reservoir for the purpose of compressing, and of retaining, a quantity of combustible gases, mixed with a proper proportion of air for its complete combustion, and at a pressure exceeding that which it is proposed to have exerted in the working-cylinder. The reservoir has precisely the same relation to the engine as has the steam-boiler to the steam-engine.

A jacket surrounds the cylinder, through which water is kept constantly circulating. The comparatively low temperature thus secured in the walls of the cylinder allows of the adoption of the same construction of piston, with metallic packing-rings, which has become standard in steam-engines. It also permits the use of the same methods of lubrication.

A diaphragm composed of several layers of wire-gauze, similar to that which gives the Davy safety-lamp its security, is placed at the openings through which the gaseous mixture enters the cylinder. This is of more closely woven material than that used in the safety-lamp, and is in several thicknesses instead of but one. It is probably an effective preventive of ignition of the mass of the gas inclosed in the reservoir. A similar diaphragm, but of much smaller area, allows a very small quantity of gas to stream continually into the cylinder, and as this current is not interrupted by the closing of the induction-valve, its little jet burns constantly and is always ready to ignite an entering charge.

Should a flame, by any accident, reach the reservoir, the expansion of the confined gas in consequence of its explosion simply opens the safety-valve, which is given considerable area, and no harm is done.

Where liquid hydro-carbons are used in place of gaseous fuel the reservoir is filled with air, and carburization takes place between the reservoir and the working-cylinder.

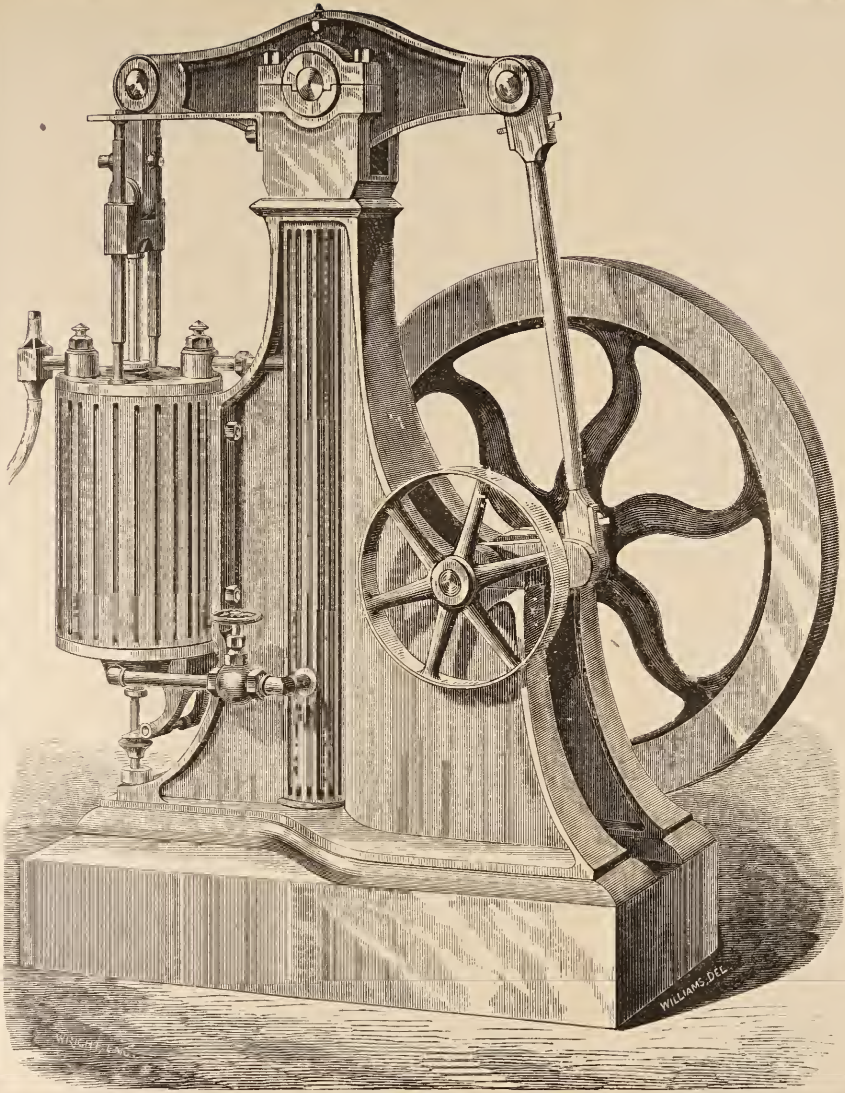
WRIGHT, ENG.
WILLIAMS, DEL.

FIG. 74.—Brayton's high-pressure gas-engine.

The induction-valve is protected from the action of the hot gases by the safety-diaphragm, which is interposed between it and the cylinder. The eduction-valve is unprotected, and to avoid serious injury it is made of well-fitted steel.

The operation of the engine is precisely similar, in the action of the engine proper and in the distribution of pressures, to that of the steam-engine. The action of the impelling-fluid is not explosive, as it is in every other form of gas-engine of which I have knowledge. Upon the opening of the induction-valve, the mixed gases enter, steadily burning as they flow into the cylinder, and the pressure, from the commencement of the stroke to the point of cut-off, as is shown by the indicator-diagrams, is as uniform as that observed in any steam-cylinder. The maximum pressure exerted during the experimental trial, and while the engine was doing somewhat more than its full rated power, was about 75 pounds per square inch at the beginning of the stroke, gradually diminishing to 66 pounds at the point of cut-off, where the speed was nearly a maximum, and thence declining, in accordance with the law governing the expansion of gases.

Complete combustion is insured by thorough mixture. This is accomplished by taking the illuminating-gas and the air, in proper proportions, into the compressing-pump together, and the mixture here made becomes more intimate in the reservoir and in its progress toward the point at which it does its work.

165. *Trial of the Brayton engine.*—The results of the trial were thus stated:

The engine rated at 5 horse-power developed, as a maximum, rather more than its rated power. Its mean power during the test, as determined by the dynamometer, was 3.986 horse-power, the indicator showing at that time 8.62 horse-power developed in the cylinder.

The amount of gas consumed averaged 32.06 cubic feet per dynamometrical horse-power per hour.

The excess of indicated over dynamometrical horse-power is to be attributed to the work of driving the compressing-pump and to the friction of the machine. The greater portion of this appears both on the debit and credit sides of the account, since, although expended in the compressing-pump, it is restored again in the driving-cylinder.

166. *Description of figures—Brayton's engine.*—Fig. 74 represents a single-acting engine of this class.

In the sectional view of the working-cylinder, (Fig. 75,) A is the cylinder, surrounded by a water-jacket to prevent overheating, and fitted with a piston. As this is exposed to the direct action of the ignited gases, it is protected by a separate plate of cast-iron, with a layer of asbestos intervening.

The upper end of the cylinder, used as a condensing-pump, is supplied with an induction-valve, *a*, and an eduction-valve, *b*. It is obvious that at each down-stroke of the piston the cylinder will be filled with the gaseous compound through the valve *a*, and upon the up-stroke the same charge will be forced through the valve *b* into a reservoir.

At the bottom of the cylinder, and below the range of the down-stroke of the piston, is formed a chamber, in which are placed two or three diaphragms of fine gauze-wire, K K, kept in position by two outside plates which are perforated. This partition is called the intercepter, because it serves to guard the passage leading from the reservoir, and prevents the flame from communicating therewith. The partition is so located that all gases consumed in the engine must pass through it; a screw-valve, when open allows the gaseous compound to flow through the pipe

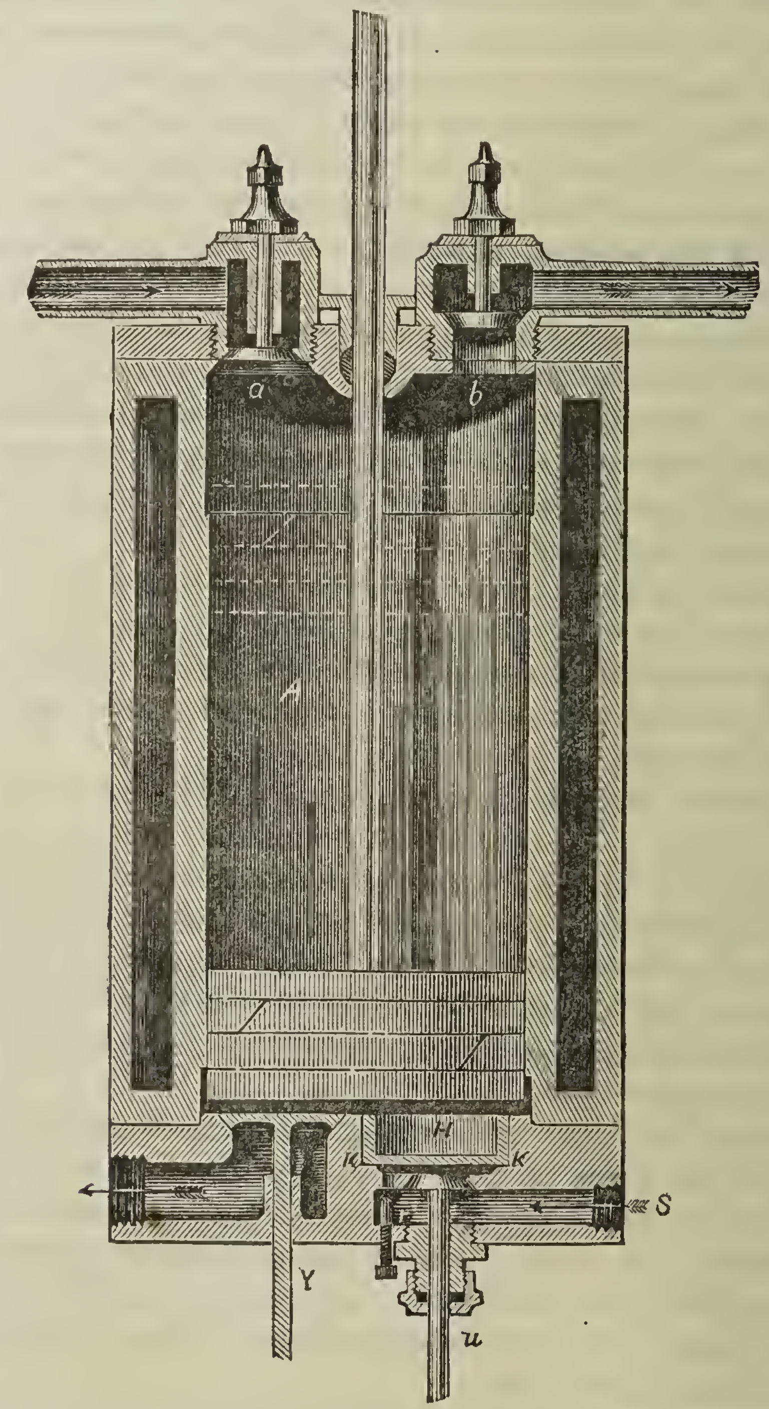

FIG. 75.—Section of Brayton's gas-engine cylinder.

S to the valve-chest, which is similar to that of the steam-engine. The induction-valve *a* is opened for every up-stroke of the piston by means of a cam on a rock-shaft, thus admitting the compressed gases through the intercepter to the cylinder. As previously indicated, the gaseous compound is applied to drive the engine while it is undergoing expansion after ignition. It is, therefore, necessary to provide for maintaining a constant flame upon the surface of the intercepter. For this purpose a small aperture is made through the wall of the valve-seat, the area of which is regulated by means of the pointed screw *r*.

The most economical performance of a gas-engine previously recorded, so far as the writer is aware, is that of the Otto & Langen engine, exhibited at Paris in 1867.* This engine was reported by Prof. Karl Jenny, of Vienna, to have consumed 38.10 cubic feet of gas per horse-power per hour.

The best performance claimed for the Lenoir and Hugon engines is 70 and 74 cubic feet, respectively. M. Tresca reported from the *Conservatorie des Arts et Metiers*, Paris, a consumption of 95.28 cubic feet.

167. *Conclusions from results of trials of the Brayton engine.*—The conclusions based on the results of the trial of the American gas-engine just described were:

1st. That the method of utilizing the power obtainable from the combustion of gas as here adopted is, so far as the writer is aware, quite new, and is most advantageous in its results.

2d. That in this engine combustion is proven by the application of the indicator not to be explosive, but to occur in a progressive manner, developing a very uniform pressure, never equalling that in the reservoir, and varying in the driving-cylinder precisely as does steam-pressure in the cylinder of the steam-engine.

3d. That this method of utilizing gas-power is an exceptionally economical one.

4th. The liability of explosion within the reservoir, as well as of any danger arising from such explosion, should it ever occur, is very carefully provided against.

5th. That the interior surface of the cylinder presented no evidence of overheating, or of injury from any cause, at the termination of the experiments.

6th. The same remark applies to the safety-fuses or diaphragms.

7th. The valve-gear of this engine, with its variable cut-off, is an effective and valuable feature.

8th. That the mechanism and general design of the later style of this engine are excellent.

168. ADVANTAGES OF NON-EXPLOSIVE GAS-ENGINES.—The advantages claimed for this class of engines are well stated in an opinion of the late Charles M. Keller, after an examination of the Brayton gas-engine:

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* See the very complete and valuable report of Dr. F. A. P. Barnard on machinery and processes.

"This gas-engine will occupy about the same space as a steam-engine of equal power, and hence will save all the space required for the boiler and its connections with the engine, which is much greater than the space occupied by the engine alone. It avoids all the risk attending the use of the steam-engine, such as fires and explosions. * * *

"This engine saves the expense of an engineer, as there is no boiler. * * * And what is of great importance in the question of economy, is the fact that it saves all the time and fuel required in the use of a steam-engine to get up steam."

To the above it may be added that the gas-engine is always ready for work, and stopping and starting, however often, involve no additional expense. They make no ashes, and are therefore cleanly and convenient in use. They are not, in any example yet produced, however, equally economical in cost of fuel with the hot-air or the steam engine, and are, therefore, not likely to be introduced with the rapidity which might be expected, were this point also in their favor. There are very many situations, however, in which they may be used where the use of the other heat-engines is entirely inadmissible, and quite a large market is open to them.

The adoption of the vapor of petroleum and of the naphthas as a combustible, in place of illuminating-gas, which has also been successfuly accomplished by the inventor of this engine, is a very important step in the direction of economy of cost of fuel, and makes it more certain that this or some similar form of gas-engine will find a wide range of application.

169. THE OTTO & LANGEN GAS-ENGINE.—Several of the engines of Otto & Langen above referred to were exhibited at Vienna. In these machines, the explosion of the gaseous mixture *shoots* the heavy piston and its attachments upward. When at the upper limit of its range, it is caught by a pawl, and its weight, while descending, turns the driving-shaft. The charge is fired by the electric spark. The machine is compact and works with great economy, but is rattling and very noisy, and it therefore impresses the professional observer, at least, as being unmechanical in design, and as likely to be expensive in repairs. It is claimed, however, to be a durable, as well as in other respects a satisfactory, motor, and it is stated that a considerable demand has arisen for them.*

170. *Trial of the Otto & Langen engine.*—In a note on the gas-engine of Messrs. Otto & Langen, and an account of experiments made on an engine of this kind, by M. Tresca, member of the council, which was published in the "*Bulletin de la Société d'Encouragement pour l'Industrie Nationale*," he reports in substance as follows:

The gas-engine of MM. Otto & Langen, which was in operation at the Exposition of 1867, was at the time the subject of numerous experiments. The report of those made by us is found in the *Annales du Con-*

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*See Verhandlungen des Vereins fur Gewerbfleiss in Preussen, 1868.

servatoire, and in the *Memoires* of the Technical Society of Hanover. It there appears that the consumption per horse-power and per hour is reduced by the new arrangement to about 1,250 liters (46 cubic feet) of gas, *i. e.*, one-half less than that of similar engines constructed in France for some time past.

The diagrams taken from these engines exhibit the causes of this important improvement. In the atmospheric engine of MM. Otto & Langen, the stroke of the piston is variable, and this piston ceases to rise at the precise moment when the internal pressure ceases to be greater than the pressure of the atmosphere. In double-acting engines, on the contrary, it happens very frequently that toward the end of the stroke the internal pressure becomes considerably lower by the condensation resulting from the combination of the oxygen and the hydrogen, and that an expenditure of power is required to overcome the difference between the internal and external pressures during the latter portion of the stroke of the piston.

This negative work, which must be subtracted from the work developed during the period of expansion, exercises a visible influence; and the suppression of this cause of enfeebled action must necessarily be synonymous with an increase of useful effect.

An excellent work by M. Schmidt, the engineer of the Parisian company,* exhibits these advantages, and the company has for several years past been building engines of this kind for less than one horse-power.

M. Tresca availed himself of the first opportunity to institute regular tests with the engines purchased by M. Hardy for his shops, and we shall hereafter give the results obtained in this way at the beginning of 1870.

171. The engine experimented with was numbered 69, and its principal dimensions were:

	Meter.
Diameter of piston	0. 222
Maximum stroke of piston	1. 052
Diameter of water-jacket	0. 400
Height of water-jacket	0. 965

It is evident that the engine has very large dimensions compared with the work produced; but it economizes, on the other hand, the ordinary space of the boiler, which commonly takes up more room than the moving parts.

The following are the results of the different experiments which he was able to make.

First Experiment, March 27, 1870.—Pressure of gas, 30.5 millimeters.

Duration of experiment, 4 hours.

Number of revolutions during this time, 20,563.

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* See Annuaire de la Société des anciens élèves des Écoles d'arts et métiers; 1867; XX^e année; p. 231.

Length of arm of brake, $0^{m}.75$.

Weight at extremity of arm, 10 kilograms.

$$T=\frac{628\times 0.75\times 10\times 20563}{4\times 3600\times 75}=0.896 \text{ horse-power.}$$

Consumption of gas during the four hours of the experiment, 4070 liters; or, per hour, 1017.5 liters.

Consumption per horse-power and per hour, $\frac{1017.5}{0.896}=1135.6$ liters, (39.4 cubic feet.)

In the following experiments, we estimate the consumption of gas by the burners at 60 liters per hour, which reduces the consumption corresponding to the work produced to $1^{m}.175-0^{m}.060=0^{m}.0575$.

If we estimate the heat disengaged by the combustion of each cubic meter of gas at 6000 calories, we perceive that total heat of combustion would be $0.9575\times 6000=5745$ calories.

We find in the water surrounding the cylinder of the engine an amount of heat represented by 1048.8 calories per hour. This amount of heat was determined by the rise of temperature of 110 liters of water from 23° to 64°, or 41° in 4 hours 18 minutes; total, $110\times 41=4510$ calories, and in one hour 1048.8 calories. By comparison with the amount expended, we find that the water carries off the fifth part of the amount produced by combustion. In fact, the proportion would be much greater if we took into account the loss occasioned by the cooling of the water-jacket.

Viewed with reference to the mechanical equivalent of heat, the total expenditure of 5745 calories, for a work of 0.896 horse-power, representing during one hour $270,000\times 0.896$, we have for each calorie a useful work of

$$\frac{270000\times 0.896}{5745}=42.1 \text{ kilogram-meters.}$$

To vary the velocity of the engine, a small cock is opened and closed so as to increase or diminish the flow of the gas; the distribution remaining the same, the proportions of the explosive mixture vary according to the opening of the supply-cock.

The engine is regulated so that, at each revolution, a volume of air and of gas is introduced, which is represented by $0.145\times\frac{\pi D^2}{4}=5.61$ liters; where $0^{m}.145$ is the distance from the bottom of the cylinder to the lower part of the piston at the moment when the supply is cut off.

During the four hours of the experiment, the gas-meter indicated a total consumption of 4070 liters, including that consumed by the burners; there remains, therefore, for the consumption of the machine $4070-(60\times 4)=3830$ liters. The total number of revolutions of the engine being 20,563, the volume of gas used per turn will be $\frac{3830}{20563}=0.1862$ liters. The total volume of the mixture of air and gas being 5.61 liters, it is easy to determine the proportion of air, equivalent to $\frac{5.61}{0.1862} = 30.12$ times the volume of the gas.

172. *Second experiment*, April 3, 1870.—Pressure of gas, $36.00^{mm.}$; determination of the work of the engine per minute:

Duration of the experiment, 1 hour, or $3600''$.

Number of revolutions during this time, 4,917.

Arm of brake, $0^{m}.75$.

Weight of the extremity of arm, 10 kilograms.

$$T = \frac{6.28 \times 0.75 \times 10 \times 4917}{3600 \times 75} = 0.857 \text{ horse-power.}$$

Consumption in 1 hour, 1085 liters.

Consumption per horse-power and per hour, $\frac{1085}{0.857} = 1266$ liters, (44 cubic feet.)

In this experiment, the amount of gas used by the burners was directly determined during the experiment by employing a special meter. The consumption was as high as 65 liters an hour.

The amount of heat expended is $6000 \times 1.020 = 6120$ calories.

The amount of heat found in the water being 963.7 calories, determined by the rise of temperature of 107 liters of water from 33 to 42 degrees, or 9 degrees in an hour, the ratio of the amount of heat expended to the amount absorbed is $\frac{6120}{963} \doteq 6.3$.

The work of one calorie is represented by the ratio

$$\frac{270000 \times 0.857}{6120} = 37.8.$$

The proportion of air is less than in the first experiment; the volume of gas is 1020 liters, the number of revolutions 4917; which gives $\frac{1020}{4917} = 0.207$ liters of gas per revolution. The volume of air and gas being always 5.61 liters, the proportion of the mixture represented by $\frac{5.61}{0.207} = 27.10$

173. *Third experiment*, April 3, 1870.—Presence of gas, 36.00 millimeters.

Determination of the work of the engine per second:

Duration of the experiment, 30 minutes, or $1,800''$.

Number of revolutions during the time, 2,446.

Arm of the brake, $0^{m}.75$.

Weight at the extremity of the lever, 5 kilograms.

$$T = \frac{6.28 \times 0.75 \times 5 \times 2,446}{1,800 \times 75} = 0.426 \text{ horse-power.}$$

Consumption during 30 minutes, 280 liters, or 560 liters per hour.

Consumption per horse-power and per hour $\frac{560}{0.426} = 1314.5$ liters, ($45\frac{1}{2}$ cubic feet.)

In this experiment, the amount of heat expended is $6000 \times 0.506 = 3036$ calories; the heat absorbed by the water being 321 calories per hour, determined by the rise of temperature of 107 liters of water from 47° to 48°.5, or 1°.5 in thirty minutes; the rates of the heat expended to the heat absorbed is $\frac{3036}{321} = 9.4$.

The work of one calorie is represented by $\frac{270000 \times 0.426}{3036} = 37.8$ kilogram-meters.

To determine the proportion of air and gas in the explosive mixture, we have the following elements: 253 liters of gas for 2,446 revolutions of the engine, or $\frac{253}{2446} = 0.103$ liter of gas per revolution. Since the total volume of the mixture is always 5.61 liters, the proportion of the mixture will be represented by the ratio of $\frac{5.61}{0.103} = 54.46$.

174. *Fourth experiment*, April 3, 1870.

Determination of the work of the engine per second:

Duration of the experiment, 30 minutes, or 1,800″.

Number of revolutions during this time, 2,399.

Arm of the brake, $0^{m}.75$.

Weight placed at the extremity of the arm, 5 kilograms.

$$T = \frac{6.28 \times 0.75 \times 5 \times 2399}{1800 \times 75} = 0.418 \text{ horse-power.}$$

Consumption during 30 minutes, 280 liters, or 560 liters per hour.

Consumption per horse-power and per hour $\frac{560}{0.418} = 1339.7$ liters, (46 cubic feet.)

Heat expended, $6000 \times 0.5088 = 3052.8$ calories.

The amount of heat taken up by the water was not determined.

The work of one calorie is represented by—

$$\frac{270000 \times 0.418}{3052.8} = 36.96 \text{ kilogram-meters.}$$

The proportion of air and of gas in the explosive mixture is determined by the following elements: 280 liters of gas for 2,399 revolutions of the engine, or $\frac{280}{2399} = 0.116$ liter of gas per revolution. The proportion of the mixture is exhibited by the ratio $\frac{5.61}{0.116} = 48.36$."

175. *Results of trial of the Otto & Langen gas-engine.*—We will collect these results in the following table:

General table of results.

Dates of the experiments.	Numbers of the experiments.	Duration of experiments.	Velocity of the machine per minute.	Work developed.	Consumption per horse-power and per hour.	Ratio of the heat developed to the heat lost.	Work produced per calorie expended.	Proportion of gas in 100 volumes of explosive mixture.
		h. m.	*Revolutions.*	*Horse-power.*	*Gallons.*			
March 27, 1870	1	4 00	85. 67	0. 896	249. 945	5. 4	42. 1	3. 31
April 3, 1870	2	1 00	81. 95	0. 857	278. 646	6. 3	37. 8	3. 68
April 3, 1870	3	30	81. 53	0. 426	289. 321	9. 4	37. 8	1. 83
April 3, 1870	4	30	79. 96	0. 418	294. 867		36. 96	2. 06
Mean	....	....	....	....	278. 184	....	....	....
EXPERIMENTS OF SHORT DURATION MADE LATER BY M. HARDY.								
April —, 1870	1	15	76. 6	0. 80	286. 120	....	....	....
April —, 1870	2	15	58. 7	0. 74	226. 042	....	....	....
April —, 1870	3	15	65. 9	0. 69	255. 095	....	....	....

NOTE.—The kilogram = 2. 205 pounds avoirdupois; the meter = 3. 281 feet = 39. 372 inches; the liter = 61.0165 cubic inches = .0353 cubic feet = .264 gals.= 1.05 qts.; the calorie is the quantity of heat required to raise one kilogram of water one centigrade degree in temperature; the horse-power = 75 kilogram-meters per second, or 542½ foot-pounds, equivalent to 32, 549 foot-pounds per minute. —R.H.P.

"It results from this table that the engine, No. 69, has never developed one horse-power; that the consumption of gas has never reached 1,350 liters per horse-power and per hour,* even when the proportion of gas in the explosive mixture was limited to 2 per cent. of the total volume; finally, that the utilization is still greater for a lower velocity, which would lead to the conclusion that the most favorable conditions correspond to 60 revolutions per minute.

Since the engine was put up, it has always worked well, and we may consider the reduction of the consumption of gas in atmospheric engines to one-half of what it formerly was, as a fact definitely accomplished by the invention of Otto & Langen. Many of the lesser industries may henceforward avail themselves economically and satisfactorily of these engines to within the limit of ¾ horse power, especially if the loss of water can be diminished by a well-conducted circulation, as indeed everything leads us to expect that it can. It would be very desirable if the noise made by the engine at every stroke could be lessened.

The above records of the experiments of M. Tresca are the best which have come into the hands of the writer, and the conclusions given are entitled to great weight as the opinions of one of the leading European authorities.

176. *Source of the economy of the Otto & Langen engine.*—The exceptional economy of fuel claimed, with probable justice, for this machine is, in the opinion of the writer, its only special recommendation. This

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* Equivalent to 47.655 cubic feet per horse-power per hour.—R. H. T.

is probably due principally to the extreme rapidity with which the piston is projected upward at each explosion of gas, the work of expansion being thus utilized before sufficient time has elapsed for any serious amount of condensation to occur by contact with cold surfaces, or for any considerable cooling of the mass of the permanently gaseous products of combustion. High piston-speed is evidently a condition of economy with the gas-engine, as well as with the steam-engine, or wherever the expanding fluid is inclosed within a comparatively cool chamber or within one having walls of a material which is a good conductor of heat. Avoiding this loss by condensation within the working-cylinder, the efficiency of the gas-engine will be proportionably increased above 0.4 of that due the total heat of combustion.

177. RANKINE ON GAS-ENGINES.—In referring to gas-engines, Rankine gives the following as the theoretical treatment: Where $p_0 =$ atmospheric pressure, $p_1 =$ pressure above vacuum, immediately after explosion, $p_2 =$ the final pressure measured from the same point, $p_e =$ mean pressure effective, $r =$ the ratio of explosion, $H =$ the available heat of explosion per cubic foot of the explosive mixture, $W =$ the indicated work per cubic foot, and $W_1 =$ the work at maximum efficiency.

Then if $p_1 = 5$ atmospheres $= 10{,}580$ pounds per foot, $H_1 = 2.5\,(p_1 - p_0) = 21{,}160 =$ about $\frac{3}{8}$ *total heat* of explosion, $p_2 = p_1\,r^{\frac{7}{8}}$, nearly.

$$W = 2.5\,(p_1 - p_2) - 3.5\,(r - 1)\,p_2 + (r - 1)\,(p_2 - p_0)$$

$$p_e = \frac{W}{r}$$

$$W_1 = 2.5\,(p_1 - p_0) - 3.5\,(r - 1)\,p_0.$$

The theory of the gas-engine is as simple as that of any other heat-engine; but it is evident that the determination of constants and the collection of data are exceptionally difficult.

CHAPTER VIII.

HYDRAULIC MOTORS.

WATER-POWER AND STEAM-POWER COMPARED; CHARACTERISTICS OF HYDRAULIC MOTORS; THE TURBINE WATER-WHEEL; EFFICIENCY; COST; THE CAPRON WATER-WHEEL; GWYNNE & CO.'S GIRARD TURBINE; RIETER & CO.'S JONVAL WHEELS; ROY & CO.'S WHEELS WITH FREE-DISCHARGE; COLLADON'S "FLOATING WHEEL;" STRAUB'S VERTICAL WHEELS; NAGEL & KAEMP'S FOURNEYRON "PARTIAL TURBINES;" THEIR ARRANGEMENT; ESTIMATES OF THEIR EFFICIENCY AND POWER; THIME'S FOURNEYRON-JONVAL WHEEL; PRINCIPLES OF CONSTRUCTION OF WATER-WHEELS.

178. WATER AND STEAM-POWER COMPARED.—The hydraulic motors form a class of prime movers which had once far greater range of application than since they have been so extensively superseded by steam-engines. They still remain, however, second only in importance, as a class, to the heat engines.

Formerly, when steam-engines of even the best construction consumed ten pounds of coal or more per horse-power per hour, when the cost of manufacture was vastly greater than to-day, and when transportation and repairs were matters of vastly greater expense than now, water-power was so much less expensive that the location of mills and manufactories was determined by the availability of mill-privileges, rather than by proximity either to the source of supplies or to the market.

This is now all changed; steam-engines of the best construction, and of moderate power, may be obtained with a guarantee of an expenditure of not exceeding 2½ pounds of coal per horse-power per hour, and cost of maintenance has become comparatively slight. The usual dominant consideration in locating any manufacturing establishment is, consequently, proximity to the market and convenience of transportation.*

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* The cost of the water-power equipment at Lowell was, for canals and dams, $100, and for wheels, &c., another $100, per horse-power. But this, as a first experiment, was more costly than a similar equipment need be. At Saco the expense incurred was $175 per horse-power; but at a later period, for turbines with high heads, the expense would be less. A construction and equipment, solidly carried out, with the latest improvement in wheels, would not cost over $200 per horse-power, and would, under favorable circumstances, cost less. An estimate at Penobscot was for $112.50 per horse-power. If the construction be with wooden dams, and the equipment with lower-grade wheels, then the cost would be about $50 per horse-power; and although the construction would be less permanent than the more solid, it would outlast any steam-apparatus. On the other hand, Fall River estimates of steam-equipment, exclusive of foundations and engine-houses, run from $100 to $115 per horse-power. A Boston authority gives $115 per horse-power for nominal 300 horse-power and upward, inclusive of

It thus happens that now only such privileges are sought along the banks of streams as fulfil this primary requisite, and large establishments are erected where, a few years ago, sharp competition by water-supplied localities forbade apparently a hope of success. It is this change which has built up such a wonderful cluster of great mills at Fall River, Mass., in spite of the rivalry of their long-established and well-known competitors along the Blackstone and Merrimac Rivers.

179. HYDRAULIC MOTORS.—It has by no means followed, as a consequence of the improvement of the steam-engine, that the water-wheel has been driven out of use. On the contrary, the latter has been vastly improved, especially in the United States, where the opening of the immense fields of the West and the growth of manufactures have caused the utilization of thousands of the best-located mill-sites along the many rivers and streams which intersect that part of our country. To supply that market, hydraulic motors have been demanded of which the requisites were primarily cheapness of first cost and repairs, and secondly, economy in consumption of water. But the second quality is, to a certain degree, associated with the first, since, where a given amount of water is available under a fixed head, a smaller and, other things being equal, a cheaper wheel can be put in to utilize that fall where great economy is secured than where the wheel chosen has a low efficiency. In the United States, where capital is far less concentrated than in Europe, and where it is worth something more than 7 per cent., these considerations have greater weight than there, where manufacturers are more frequently wealthy, and where the rate of interest on capital is but little more than one-half as great, while the fuel for steam-engines is more expensive also, and water-power less available, than in the United States.

The efforts of American inventors and of manufacturers have been long and earnestly directed to the cheapening of this class of motors, as well as to the increase of their efficiency, and their success has been most encouraging.

180. THE TURBINE WATER-WHEEL.—The most effective form of hydraulic motor for moderately high falls was formerly considered to be the overshot water-wheel; but recently, the turbine has been made to yield equally high efficiency, and its far lower cost, its higher speed, its freedom from difficulty arising from the presence of ice or of back-water, and its other advantages, have made it the only class now generally used. All of the three classes of turbine wheels, the outward, the inward, and the parallel flow, are constructed by builders of reputation, and give good results.

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foundations and masonry. Similarly a Portland authority places it at $100 per horse-power. The actual cost of steam-equipment in the water-works of various cities of the United States varies from $150 to $300 per horse-power.

As to the cost of work done, it appears that in Philadelphia in 1867 the cost of raising water by water-power was only $2\frac{1}{2}$ cents per 1,000,000 gallon-feet; whereas the cost by steam-power was in four cities $8\frac{3}{10}$, $11\frac{1}{10}$, $19\frac{1}{10}$, and $29\frac{2}{10}$ cents, with coal at $5.50 per ton.—*The Water Power of Maine.*

181. *Efficiency and cost of turbines.*—The average performance of a well-designed and well-built wheel gives not far from 75 per cent. of theoretical power of the fall. This figure is, however, often exceeded. Thirty years ago, Mr. Uriah A. Boyden designed Fourneyron wheels, which gave 78 per cent., and in 1846 he was paid for 88 per cent. on a contract with the Appleton Company of Lowell, Mass.

Turbine wheels, to secure such very high efficiency, must be finished, as well as designed and constructed, with exceedingly great care. Cheap wheels are, however, made regularly for the market by builders in the United States, which, when set at work under favorable conditions, will yield a percentage quite up to the first figure given.

As an illustration, one of our manufacturing firms makes a wheel about 6 feet in diameter which sells for less than $1,800. Under a 9-foot head, it is rated at over 110 horse-power, at about 55 revolutions per minute, and its builders present evidence that, driving a saw-mill, 60,000 feet of white-pine logs have been turned out in twelve hours, and an average made of 35,000 in eleven hours.

Another builder makes a 48-inch wheel for $550, and rates it, with probable correctness, at nearly 45 horse-power under 10 feet head and 80 revolutions, and at 80 horse-power at 20 feet head and 115 revolutions.

These wheels are made up in lots for the market, not singly and to order, as is done in other countries, and this fact of the adoption of what is known as the "American system" of manufacturing has an important influence in reducing cost.

The efficiency of those wheels at "part-gate" is very greatly affected by the method of regulation. In some cases the speed-governor is so attached as to adjust a set of slide-valves in the passages between guide-blades. In other cases, the blades themselves turn on axes near the inner ends, and in the standard Fourneyron turbine the gate usually consists of a drum between the wheel and the casing which is hoisted or lowered to increase or decrease the speed of the wheel. Rankine states the loss of efficiency for average practice as follows:

Ratio of actual to full gate	$\frac{1}{5}$,	$\frac{2}{5}$,	$\frac{1}{2}$.
Ratio of efficiency to maximum	$\frac{1}{2}$,	$\frac{2}{3}$,	$\frac{5}{6}$.

The loss of efficiency will vary very greatly with the character of the regulating-apparatus. In some cases the loss is slight, while in others it is very great at the same degree of opening. A very large number of regulating-devices and forms of gate have been patented in the United States. These losses are least where the flow is adjusted by varying the size of the openings, or by changing properly the direction of the guide-blades, and they are greatest where the variations of velocity of the stream are greatest, or where sudden contractions of the channel are permitted. It is in this direction that some of the best work in the improvement of the turbine has been done.

182. THE CAPRON TURBINE.—The American section contained but one wheel of this class, a plain, well-finished turbine, exhibited by the Capron

Manufacturing Company, of Hudson, N. Y. It received some attention as illustrating the fact that builders in the United States were engaged in this class of work. It is unfortunate that so large an industry was so poorly represented in number and variety. The following improvements constitute the main features of this wheel: the buckets are detachable, being made with a V-shaped flange or bead upon their upper and lower edges, which fit into corresponding grooves on the upper and lower disks of the wheel. By this arrangement two important advantages are attained. The buckets may be polished before being inserted in the wheel, thus securing a considerable reduction in friction and a corresponding economy in power; and if one or more of the buckets should accidentally become broken, it may be replaced with little delay, and without rendering any of the other buckets or either of the disks useless. In many other wheels the breakage of a bucket makes it necessary to put in a new wheel or a section of a new wheel, occasioning long and expensive stoppages while the repairs are being made. The top of the mouth of the scroll is detachable, giving easy access to the wheel and scroll for removing obstructions that may get into the wheel; this also makes it possible to fit in a new gate, or to refit the old one, without removing the wheel from the scroll or detaching the scroll from the water-box.

183. GWYNNE & CO'S. GIRARD TURBINE.—The British section also contained but one wheel. This was a Girard turbine, built by Gwynne & Co., of London. Its most striking peculiarity consisted in the method of regulation. The circumference was divided into four quadrants, which were alternately provided with guide-curves and closed up. One-half of the wheel, therefore, did no work. The gate was so fitted that when the wheel was running at full power it lay between the wheel and casing at the blank quadrants. When regulation was necessary, it was swung around over the working quadrants, closing off a greater or less number of openings, according to the necessities of the moment. It is evident that this arrangement considerably increases the size of the wheel for a given power.

The arrangement is recommended for exceptionally great heads, or when the velocity of the ordinary wheel would be excessive. But as the efficiency of the wheel is so largely dependent upon the adjustment of its speed as a function of the height of fall, it is evident that reducing velocity will decrease efficiency. It would seem that a better plan would be to drive the turbine at the proper speed, providing against inconvenience or injury at such exceptionally high speeds by care in designing and skill in the construction of its bearings and of the machinery of transmission.

Wheels of the capacity of the American wheels above described are catalogued at £500 and £180, respectively, or not far from 50 per cent. higher price, notwithstanding the lower cost of labor and material in Great Britain. An efficiency of 80 per cent. is guaranteed. The practice of this firm is to make the steps of the shaft of lignum-vitæ, lubricating with water.

184. Rieter & Co.'s Jonval turbine.—An interesting collection was shown by Messrs. T. Rieter & Co., of Winterthur, Switzerland. It consisted of machinery and plans of very fine work done by them during a few years past. These manufacturers build the Jonval wheel, and have constructed some of a size nearly equal to the largest turbines in use in the United States. Those constructed for Bellegarde, at the junction of the Rhône and Valerine, are 8 feet in diameter, and under a fall of 40 feet, making 90 revolutions per minute, as it was stated, develop a power of 630 horses. This' firm adopt the "telodynamic" method of transmission of power, using wire rope running, at high speed, over very large pulleys. The method is that which has been introduced, with great success in some cases, by Messrs. J. Roebling's Sons, of Trenton, N. J.

185. Messrs. Roy & Co., of Vevay, presented an attractive collection of turbine wheels on a small scale, in tanks fitted with glass windows, through which their operations could be observed. This firm, it is said, have constructed within ten years more than 200 Girard turbines, representing a total of 9,000 horse-power. These are all made with what is called a "free discharge." The wheel is not allowed to work in tail-water, but in an atmosphere of air so compressed that the water is kept back at a lower level than the wheel itself. This air-chamber which incloses the wheel, and is opened at the bottom for the exit of the stream leaving the wheel, is kept full by an air-pump worked by the turbine itself—a somewhat costly addition to the machinery. This arrangement for relieving the wheel of the drag of tail-water has unquestionable advantages, and these engineers consider them more than sufficient to compensate the extra cost of their construction. Their assertion is well sustained by their success in introducing them.

186. Colladon's "floating wheel."—The Swiss section contained a considerable number of exhibits of hydraulic machinery, one of which should be described, although a little out of place here. This was a design shown by M. Colladon, of Geneva, of a "floating hydraulic wheel" for rapid streams. One of these wheels was stated to have been at work on the Rhône, near Geneva, day and night for eight years. This wheel is a great barrel, of boiler-plate, carrying floats or paddles, by which it is turned as it floats upon the stream, revolving about an axle which may rise and fall with the tide. The wheel thus works equally well whatever the height of the water.

This wheel is rated at 12 horse-power, and is used to raise water to a height of 65 meters, (215 feet,) for the purpose of supplying the neighboring villages. It was said to have cost, with its attachments, but 10,000 francs, ($2,000.)

187. Straub's vertical wheels.—A fine exhibit of hydraulic machinery was made by Herr D. Straub, of Geislingen. One of his turbine wheels was constructed for a height of fall of 500 feet.

A more remarkable wheel was that of Millot, shown by the same exhibitor, in which, by a neat device, the inflow of water was directed into the wheel, passing from the interior into the bucket and thence outward at its discharge. The wheel was 18½ feet in diameter outside, 14 feet inside, 7 feet breadth of face, and intended to make five revolutions per minute. The exhibitor claimed for this wheel an efficiency of over 85 per cent., a result possibly, but in the opinion of many engineers not probably, attainable. Herr Straub also exhibited a breast-wheel, 16½ feet diameter, 6 feet in length, and for a fall of moderate height this is an effective wheel. The efficiency promised was 75 per cent.

188. NAGEL AND KAEMP, of Hamburg, exhibited a very interesting group of hydraulic apparatus, including four turbine water-wheels, of diameters ranging from 21½ inches to 83 inches. The ordinary method of regulation is practiced with the Fourneyron wheel as built by Nagel & Kaemp; the water enters from below, as is usual, instead of from above. The regulation is effected by altering simultaneously, by a very ingenious arrangement, the height of both guide-curves and wheel-buckets, thus altering the working depth of the wheel to suit the varying requirements of the case. The percentage of useful effect in the wheel is thus preserved nearly constant for all variations of power. The arrangement complies with theoretical requirements, and is, furthermore, practically successful. It is one of the best devices shown at Vienna. The entrance of the water below the wheel is of decided advantage, in permitting a partial balancing of the weight on the step and making the wheel far less liable to give trouble in consequence of defective lubrication at that point, the greatest difficulty usually experienced with the Fourneyron wheel. So freely does the wheel work, the exhibitors state, that they have actually in operation a wheel working under a head of but 6 inches. Another exceedingly neat device is that adopted for oiling the step. The lubricant floats on the water within a little bell surrounding the step as the air is retained within a diving-bell. Should the journal commence cutting, the particles fall down and are carried away by the water instead of choking the bearing, as usually occurs. The whole arrangement is neatly designed and well proportioned, and is an excellent piece of work.

189. Another "partial" turbine wheel, or wheel with "partial delivery," is shown, which belongs to a class already referred to. The gate swings about the axis of the wheel, closing off a greater or less number of openings through the wheel. This design is intended for great height of fall.

Another interesting device was the regulating-wheel used by this firm. An annular bucket-wheel, with floats capable of moving about axes at the inner ends, was fitted outside the turbine bucket-wheel. When the turbine was working properly, the water issued radially between these floats, leaving them in their normal positions. A disturbance of the turbine producing a change in the direction of the outflowing water, it impinged against the floats of the regulating-wheel, changing their position on their axes, and, through a properly-arranged system of gearing, caused the necessary change of position in the gate. One of those turbines, built for a fall of 138 feet, (42 meters), weighs 800 kilograms, (1,760 pounds,) and is rated at 35 horse-power.

190. *Arrangement and efficiency.*—This firm received the "*Ehren Diplom*" for their extensive and, in some respects, very superior collection of hydraulic machinery. They have furnished the writer since the close of the Exhibition with data and calculations published in the Allgemeine Deutsche Polytechnische Zeitung, 1874, and in London Engineering of February 20, 1874.

A centrifugal pump, with eccentric casing, was driven from the shafting under the floor of the machinery-hall. This pump took water from a lower reservoir, raised it through a funnel-shaped tube 5 meters (16 feet 4⅞ inches) high, whence it fell 1 meter (3 feet 3⅜ inches) into an upper reservoir. A turbine, 930 millimeters (36.61 inches) outside diameter, drove a vertical centrifugal pump. This pump also took water from the lower reservoir, and forced it through another funnel-shaped tube into the upper reservoir, altogether through a height of 5 meters. The water supplied by the two centrifugal pumps was used for driving the turbine, the available head being 4 meters, (13 feet 1½ inches.) The available cubic contents of the upper reservoir up to the level of the overflow amounted, after deducting the two tubes, to 801.44 cubic feet, and this reservoir was filled by means of one of the centrifugal pumps in exactly 101 seconds, whence the pump delivered, at its normal speed, and to a height of 5 meters, $\frac{801.44}{101} = 7.935$ cubic feet of water per second. This quantity was delivered by the vertical funnel-shaped tube, the effective diameter of which was $D = 1.055$ meters, or 41.54 inches, while the measured head of the discharge $h_1 = 0.089$ meter, or 3.5 inches.

191. The quantity of water Q_1 flowing per second over overflows of this kind is found by the known formula:

$$Q_1 = \frac{2}{3}\,\mu\, p\, h_1 \sqrt{2\, g\, h_1},$$

in which μ represents the co-efficient of discharge; p the width, or, in this case, the circumference D of the overflow, this width being in the present instance—

$D\pi = 3.315$ meters, or 10.876 feet;
$h_1 = 3.5$ inches, or 0.2917 foot; and
$2g = 64.4$ feet for the acceleration due to gravity.

According to this formula, we get, in the present case—

$$7.935 = \frac{2}{3}\mu \times 10.876 \times 0.292 \sqrt{64.4 \times 0.292},$$

whence $\frac{2}{3}\mu = 0.576$, which shows that, for such overflows of 1.055 meters diameter, the co-efficient of outflow is almost exactly the same as that found by Eytelwein for well-rounded-off weirs.

For further calculations we shall use the following symbols:

(1.) For the centrifugal pump with eccentric casing:

$Q_1 = 7.935$ = the quantity of water per second in cubic feet;

$H_1 = 16.4$ feet (5 meters) = total height through which the water is lifted;

$b = D\pi = 10.876$ feet circumference of overflow;

$h_1 = 0.292$ foot effective head;

n_1 = percentage of effect;

N_1 = effective working-power of the pump;

Therefore, taking the weight of water at 62.4 pounds per cubic foot,

$$N_1 = \frac{1}{n} \times \frac{62.4 \times 60\ Q_1\ H_1}{33000} \text{ horse-power.}$$

(2.) For the centrifugal pump:

Q_2 = quantity of water per second in cubic feet;

$H_2 = 16.4$ feet = total height through which the water is raised;

$b = D\pi = 10.876$ feet width of the overflow;

$h_2 = 0.2362$ foot effective head;

n_2 = percentage of effect;

N_2 = effective working-power of the pump;

Therefore,

$$N_2 = \frac{1}{n_2} \times \frac{62.4 \times 60\ Q_2\ H_2}{33000} \text{ horse-power.}$$

(3.) For the turbine:

$Q_3 = Q_1 + Q_2$ = quantity of water per second in cubic feet;

$H_3 = 13.12$ feet (4 meters) = total available height of fall;

n_3 = percentage of effect;

N_3 = effective working-power;

Therefore,

$$N_3 = n_3 \times \frac{62.4 \times 60\ Q_3\ H_3}{33000} \text{ horse-power.}$$

The whole effective power developed by the turbine having been used in driving the centrifugal pump with vertical spindle, we find that $N_3 = N_2$, or, by substitution, that—

$$n_3 \frac{62.4 \times 60\ Q_3\ H_3}{33000} = \frac{1}{n_2}\ \frac{62.4 \times 60\ Q_2\ H_2}{33000}; \text{ but}$$

$Q_3 = Q_1 + Q_2$, and $H_3 = 13.12$ feet; $H_2 = 16.4$ feet; whence

$$n_3 \frac{62.4 \times 60 \times 13.12\ (Q_1 \times Q_2)}{33000} = \frac{1}{n_2}\ \frac{62.4 \times 60 \times 16.4\ Q_2}{33000}.$$

$$\text{or, } n_3\, n_2 = \frac{5}{4}\ \frac{Q_2}{Q_1 + Q_2}$$

We also find, under the same conditions and for the case where the total amount of water (Q_1+Q_2) supplied by the two centrifugal pumps has been exclusively used for the working of the turbine, that the height h_2 of the effective head at the top of the funnel-shaped tube for the pump is—

$$h_2=0.2362 \text{ feet.}$$

Whence,

$$Q_2=\tfrac{2}{3}\mu\ bh_2\sqrt{2gh_2}$$
$$=0.576\times 10.876\times 0.2362\sqrt{64.4\times 0.2362}$$

Therefore, $Q_2=5.77$ cubic feet per second.

The same result is obtained in a shorter manner by division,

$$\frac{Q_1}{Q_2}=\frac{\frac{2}{3}\mu\ bh_1\ \sqrt{2gh_1}}{\frac{2}{3}\mu\ bh_2\ \sqrt{2gh_2}}=\frac{h_1\sqrt{h_1}}{h_2\sqrt{h_2}}$$

In this equation the relative values of Q_1 and Q_2 are expressed simply by the corresponding heights of fall h_1 and h_2, whence a very convenient calculation of the quantities of water by means of the easily-measured heights h_1 and h_2 is obtained. From the above equation we get—

$$Q_2=Q_1\frac{h_2\sqrt{h_2}}{h_1\sqrt{h_1}}=7.935\ \frac{0.2362\sqrt{2362}}{0.292\sqrt{292}}=5.77$$

cubic feet per second. Substituting the value of Q_1 and Q_2 into the formula given above—

$$n_3\ n_2=\frac{5}{4}\quad\frac{Q_2}{Q_1+Q_2}$$

we get

$$n_3\ n_2=\frac{5}{4}\quad\frac{5.77}{7.935+5.77}$$

or

$$n_3\ n_2=0.52$$

That is to say, the real effect produced by the turbine and by the vertical centrifugal pump together is 52 per cent. of the theoretical power of the water which is available for the turbine, or the percentage of effect from the gross power of the turbine-water to the power represented by the effect of the pump is 52 per cent. This, it must be admitted, is a very favorable result, for, supposing that the percentage of effect of the turbine is *equal* to that of vertical centrifugal pump, we get

$$n_3=n_2=\sqrt{0.52}=0.72$$

That is to say, both turbine and centrifugal pump work with a useful effect of 72 per cent. It may be, however, safely admitted that the turbine produces a greater percentage of effect than the centrifugal pump; and if we suppose, for example, and in accordance with the greater probability, that

$$n_3=0.75, \text{ we get } n_3=\frac{52\times 100}{75}=69.3 \text{ per cent.}$$

That is to say, the turbine apparently gives 75 per cent. and the vertical centrifugal pump about 70 per cent. of useful effect. It should be borne in mind that this result is obtained with a turbine of small dimensions, which represents but a power of 15 horses, and the sluices of which for the admission of the water were but two-thirds open.

192. THIME'S FOURNEYRON-JONVAL TURBINE.—A Russian exhibitor, Professor Thime, of the Institute of St. Petersburg, has attempted to secure for the Fourneyron wheel the special advantage of the Jonval turbine—that of working at any point in the fall. The whole wheel is surrounded with a casing, out of which the issuing water is led by a pipe which is carried down to the bottom of the fall and its lower end submerged. He claimed thus to have secured the advantages of accessibility peculiar to the Jonval system, without sacrificing the more satisfactory method of regulation practicable with the outward-flow wheel. The exhibitor proposes to use wheels with either vertical or horizontal axes, as may be preferred. Regulation is obtained by the adjustment of the height of openings through the wheel by means of a damper carried on the axis and sliding in the axial direction, so as to close up a larger or smaller proportion of the opening, as may be required—a system claimed to have been introduced twenty years ago by M. Charles Huot. The general design of these wheels was not good. The water passed through channels of suddenly varying sections and with sharp turns, and the loss of energy must be quite objectionable.

193. PRINCIPLES OF CONSTRUCTION OF WATER-WHEELS.—The construction of an efficient turbine water-wheel involves simple principles, but their application affords a field for the display of great engineering skill and mechanical tact. These wheels are usually divided into three great classes: parallel-flow, outward-flow, and inward-flow turbines. In either case, the aim of the designer is to transform the energy of the falling water into useful mechanical effect without losing power by splashing of the liquid or the production of heat by its friction. The water is received on the wheel without shock, transmitted with uniformly decreasing velocity, and finally leaves the wheel at the minimum velocity, which enables it to just clear the succeeding buckets as it falls.

When the water enters upon the wheel without shock and leaves it without velocity, the speed of wheel being approximately one-half that due the height of fall, a maximum economy is attained.

To secure this result, the water should enter upon the wheel with the angular velocity of the latter, and should have its velocity reversed, leaving the wheel with a velocity opposite in direction and equal in magnitude to that of the wheel itself.

CHAPTER IX

PUMPS.

Pumps; Applications; Classifications; Steam-pumps; Later forms; Decker Brothers & Co.'s pumping-engine; Cameron's, Selden's, and Earle's steam-pumps; Prunier's pumping-machinery; The Erste-Brünner-Maschinen-Fabriks-Gesellschaft; Centrifugal pumps; Their proper form; Advantages; Gwynne's exhibits; The pumps for Ferrara, Italy; Pumps of J. Bernay, Neut & Dumont, Coignard, Nagel & Kaemp; The Schiele pump; Boulton & Imray's pump; Adaptations of the centrifugal pump.

194. Classification of pumps.—The elevation of water has always been one of the most important applications of mechanical power.

Before the time of Watt the power of steam had been applied almost solely to this purpose. The steam-engines of the Marquis of Worcester, of Savery, and of Newcomen had application exclusively in this direction. The first engines of Watt were pumping-engines, and that great engineer and his competitors were the first to apply steam as a prime mover to other machinery, only after the introduction of the improved pumping-engine had relieved the miners from imminent danger of being driven from their mines by the floods of water met with at the depths then already attained. While mechanical power since that time has found a wonderfully-extended and still rapidly-widening field of application, the elevation of water, although of far less relative, is of vastly greater absolute importance than at the time of Watt's death, nearly three-quarters of a century ago.

At that time the reciprocating-pumps only were known. They still remain in use for great pressures and high lifts, but have been quite superseded recently by the rotary and centrifugal pumps wherever the great volumes of water are to be raised through moderate heights.

The three important classes of apparatus for raising water are, therefore:

(1.) Reciprocating-pumps.
(2.) Rotary pumps.
(3.) Centrifugal pumps.

The first class are frequently called "piston-pumps," and consist of a barrel in which water is intermittently displaced by a piston or a plunger with a set of valves, usually acting automatically, which compel the liquid to take the proper course when entering or leaving the pump-barrel.

The second class consists of pumps which usually have either two sets of revolving vanes, geared with each other in such manner as to seize and drive forward a certain quantity of water at each revolution by a "positive" action, or of a revolving drum, fitted with sliding diaphragms which drive the liquid along the channel which extends around the periphery of the casing, advancing radially or retiring into the drum as that channel enlarges its section or contracts.

195. STEAM-PUMPS.—Of the latter two classes, none were exhibited at Vienna which called for extended consideration, although the number of exhibits was very great. The most important exhibits were the steam-pumps; and the most interesting of the steam-pumps were types well known as having been invented in the United States and very extensively used. The latest forms of these pumps have the valves of their steam-cylinders driven by small auxiliary pistons, driven in turn by steam which is distributed by a very small valve moved by tappets upon the main piston or its rod. In these pumps there is less liability to a cessation of action when working very slowly than in older styles of pump. In the latter, reverse-steam is necessarily given before the steam and water pistons have quite reached the end of their stroke. When running at ordinary speed, the momentum of the moving mass is such that the stroke is completed, and the valve thus necessarily thrown wide open before the reverse-steam can check the onward movement. When moving slowly, however, this cannot occur, and the pump is liable to stop before completing its stroke and reversing steam. With the auxiliary valves this is far less likely to occur, and becomes almost impossible to drive the pump at so slow a speed that it cannot make a full stroke; while at high speed, from beginning to end of stroke, the full steam-pressure is obtained and a greater amount of work is usually done than could be done with the o der form of valve-movement.

196. The CAMERON "SPECIAL" PUMP was exhibited at Vienna, in the British section, by Messrs. Tangye Brothers, and is so well known in the United States as scarcely to require description. It is of the class last referred. to, and large numbers are in use in the United States, where they are made by A. S. Cameron & Co.

The pump is well designed and well made. It is compact, handy, and durable. In the illustrations (Figs. 76 and 77) it is shown in side elevation and in section.

A is the steam-cylinder shown in section, Fig. 77; C, the steam-piston; D, the piston-rod; L, the steam-chest; F, the plunger; G, the slide-valve; H, a starting-bar, connected with a handle on the outside; I I are the reversing-valves, and K K, the bonnets over the reversing-valves; N is the body-piece connecting the steam and water cylinders; B is the water-cylinder with the valve-chest bonnet removed; M is a valve-seat shown in section; the valve over it is also shown in section; T is the discharge-air vessel.

Suppose the steam-piston C moving from right to left, when it reaches the reversing-valve I it opens it and exhausts the space on

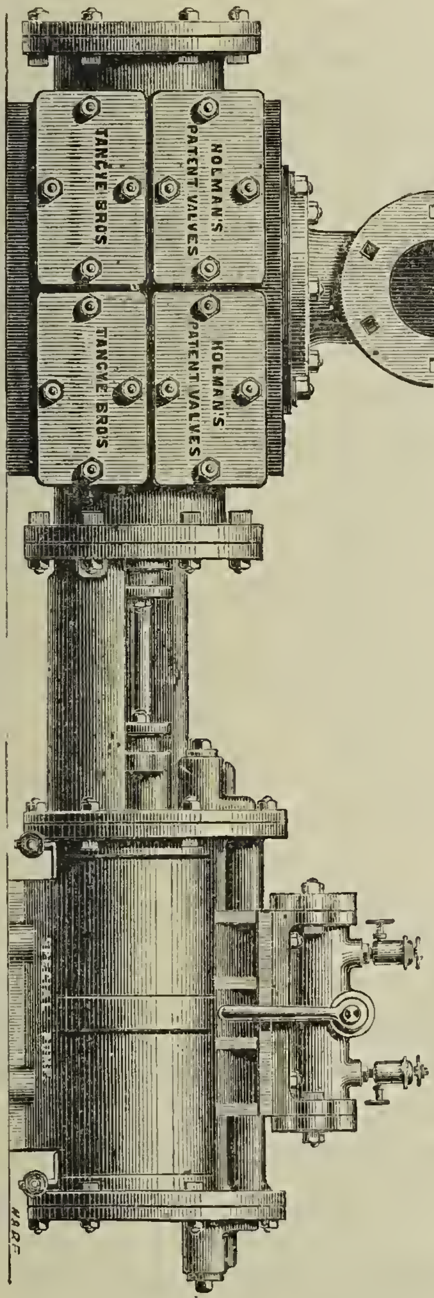


FIG. 76.—Tangye Brothers' "special" steam-pump.

the left-hand end of the plunger F by the passage E, which leads to the exhaust-pipe, the greater pressure inside of the steam-chest changes the position of the plunger F and slide-valve G, and the motion of the piston C is instantly reversed. The same operation repeated at each stroke makes the motion continuous. The reversing-valves I I are closed by a pressure of steam on their larger ends, conveyed by an unseen passage direct from the steam-chest.

A pump somewhat resembling in appearance the "special" pump was shown by Mr. McNicol, of Glasgow, the invention of Clarkson; and another pump by the same dealer, and invented by the same engineer, accomplished the same object by making the piston of the steam-cylinder of unusually great length and placing within it the valve which, working automatically, effected the distribution of steam. The pump-valves were India-rubber ball-valves. The valves of the special pump were of brass, with brass seats resting on India-rubber rings. Ten thousand of the latter pumps are said to have been made in Great Britain.

These varieties of pump are finding an enormous demand, and their manufacture constitutes an exceedingly important branch of manufacture. The English manufacturers seem to be more generally inclined to use the older form of "donkey-pump" than are our own people; but the fact that they are so generally adopting the class just described would indicate that practice in this respect in the United States is in advance of that in Great Britain.

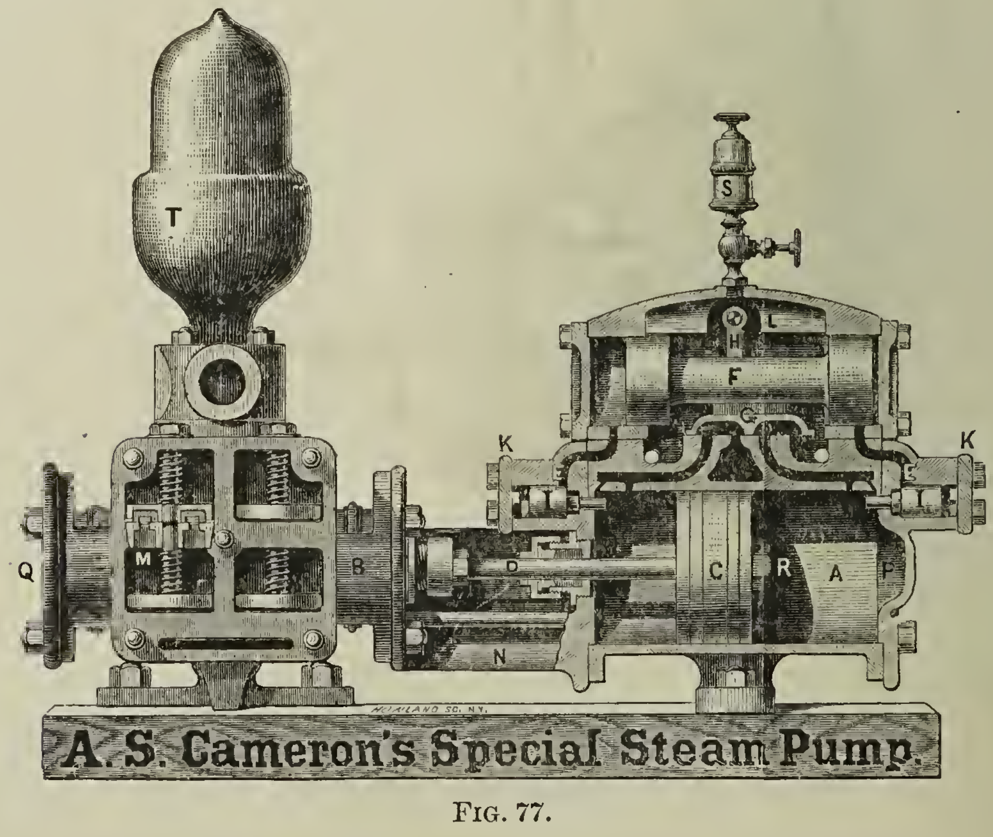
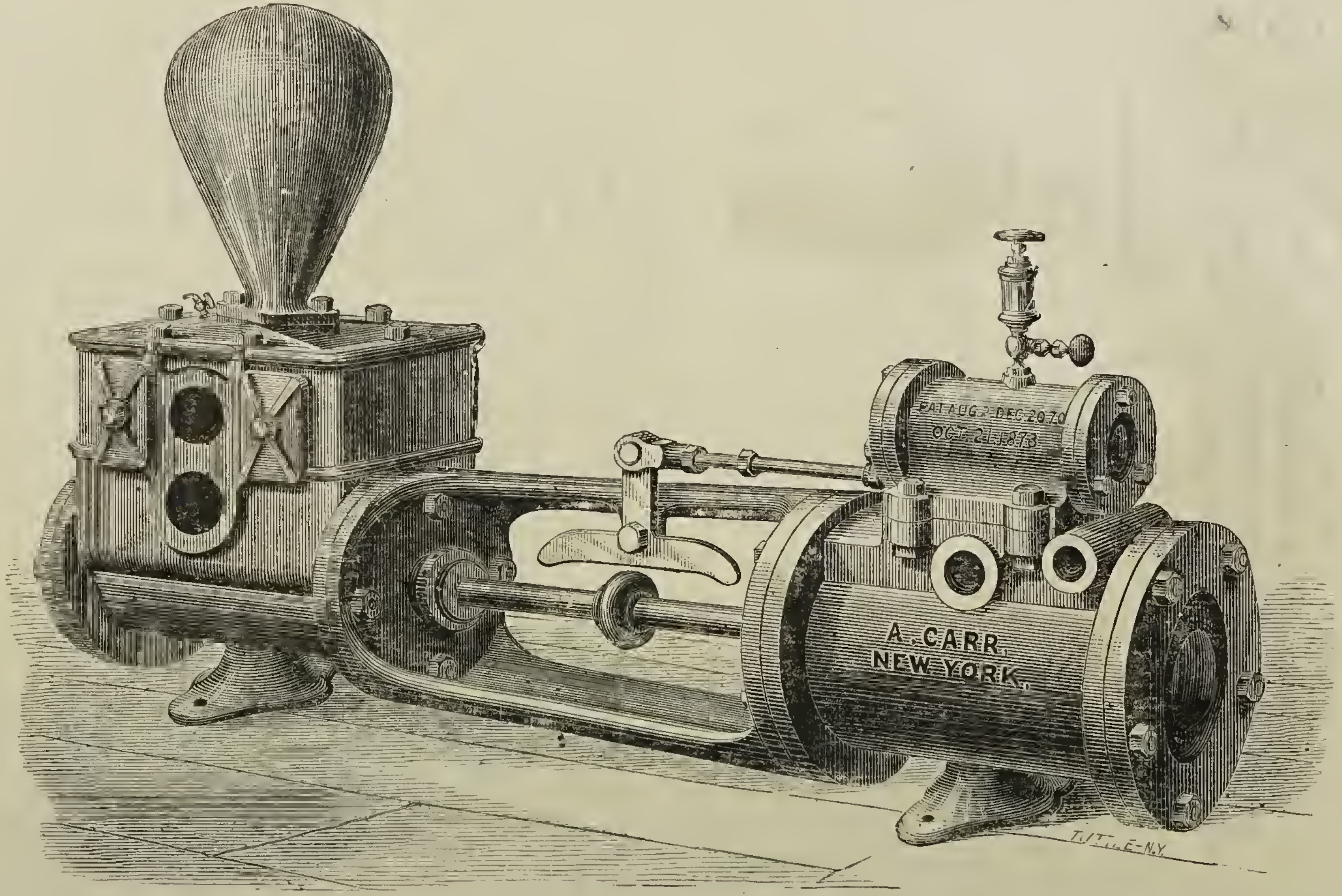


Fig. 77.

Several "donkey-pumps" were shown, one of which is a combination of what is known in America as Andrew's oscillating engine, with a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A. CARR.
NEW YORK.

Fig. 78—The Selden pump.

similarly arranged pump-cylinder, opposite each other and coupled to the same crank-shaft.

The best of the remaining pumps of this class are of the plainest design and most simple construction, and require no extended mention here.

197. There were three pumping-stations. At one of these DECKER BROTHERS & Co. had erected pumps of the style supplied by them for mining-purposes. They were 15¾ inches diameter, both in steam and water cylinders, and of 37 inches stroke. The pressure of steam was from 50 or 60 pounds and the water-pressure somewhat lower, and lower also than the pumps were designed to work against.

198. In THE SELDEN PUMP, another American design, as shown in Fig. 78, a button or disk, attached to the piston-rod at its middle point, strikes, as it reaches either end of its stroke, a bent lever connected with the valve-stem, as shown in the cut, and moves the starting-valve. It is simple in construction, positive in action, and is evidently intended more for use than ornament. The auxiliary valve, which is moved by the lever acted upon by the disk on the piston-rod, is recessed into the main valve so that they have a common seat. The pump-valves are accessible on removing one nut. They are flat, of bronze or composition, or they are sometimes faced with rubber or leather. They seat on bronze. The builder of this pump was Mr. A. Carr, of New York City.

199. In THE EARLE DIRECT-ACTING STEAM-PUMP, an American pump, exhibited by Decker Brothers, of Canstadt, steam passes into the center space of the steam-valve through a port, A; from thence the stream passes into the steam-cylinder B, causing the piston to make its stroke. When the tappet-arm D touches the valve-rod collar E, it moves the valve a short distance, uncovering the port F, when steam rushes up from below into a chamber, G, and its pressure causes the movement of the valve. The motion of the steam-piston is immediately reversed and the operation repeated at each end of the stroke. This operation of the valves allows the water to rush from the suction-pipes into a passage, J, from thence, through the suction-valves K, into the pump-cylinder H; thence it is forced by a piston up through the discharge-valves L and out at the discharge-pipe M. The elasticity of the air confined in the air-chamber equalizes any unevenness of pressure and secures a steady stream.

This pump has only one steam-valve, a single piece, impossible to break by use, fitted and proved with all the ports and passages immovably fixed in the solid casting and never needing any alteration. The valve is fitted "steam-tight," is furnished with a peculiar steam-packing, and is balanced. It is impossible to place the valve in such a position that the pump will not start the instant steam is turned on.

At the moment of reversing, the movement of the valve is in unison with the main piston; and it is claimed to be impossible for the piston to strike the cylinder-head, however fast it is moving, since, from the method of construction and connection of the valve, it will be reversed and admit steam ahead of the piston before the latter can strike the head. This point is highly important in a fire-pump, as it can then be driven at high speed without liability of breaking down. It is impossible for it to reverse its motion before it has completed the full stroke, and it uniformly delivers its maximum capacity, with an incidental advantage, the cylinders wearing equally throughout their whole length The valve is moved by steam which has completed its work in the cylinder and is about to be exhausted. The water-passages of the pump are large and direct.

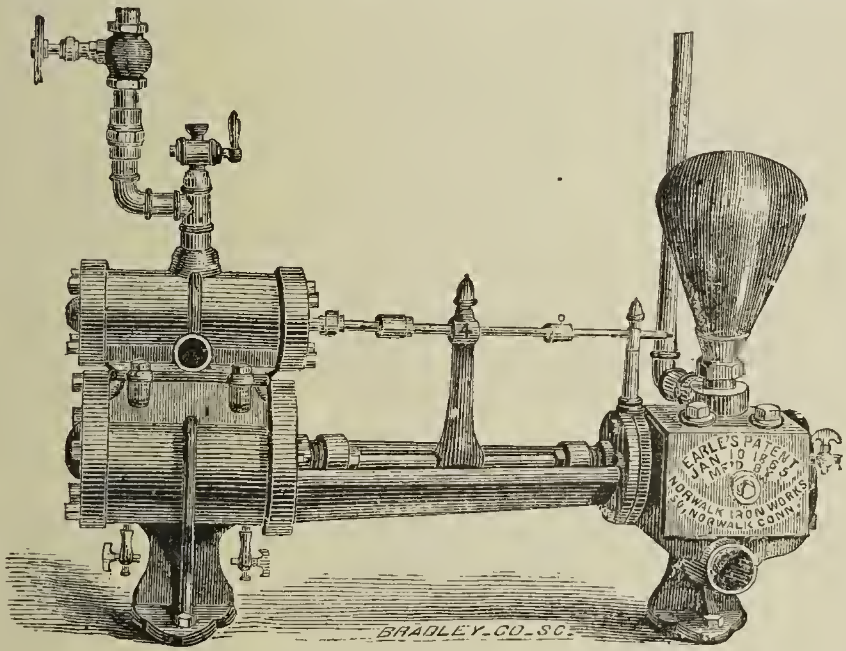


FIG. 79.—The Earle pump.

Fig. 79 is a perspective view of a boiler-feed pump.

Fig. 80 is a sectional view of the large fire-pump.

200. M. PRUNIER, of Lyons, France, erected a set of pumping-apparatus in a small building Northwest of the machinery hall. Here, two independent pumps raise water from two wells which are lined with an iron cylinder pierced with holes, very much in the same way as is customary with the tube-wells so extensively used in the United States. These tubes were one meter (3.28 feet) in diameter and 17 meters (55$\frac{3}{4}$ feet) long.

The engines were vertical, the steam-cylinders above the pumps, and the center line of both traversed the center line of the well. Each pump-barrel contained two pistons working in opposite directions. The rod which carries the lower piston was formed by continuing the steam-piston rod downward. The upper piston was carried on a hollow rod surrounding the first, and operated by a cross-head which was connected to pins on the balance-wheel at each side by connecting-rods of considerable length. These pistons were conical in general shape, and their valves were concentric India-rubber rings, having horizontal seats one above another, the smallest being uppermost. The plan here adopted was claimed to have the advantages of giving an equilibrium of weights

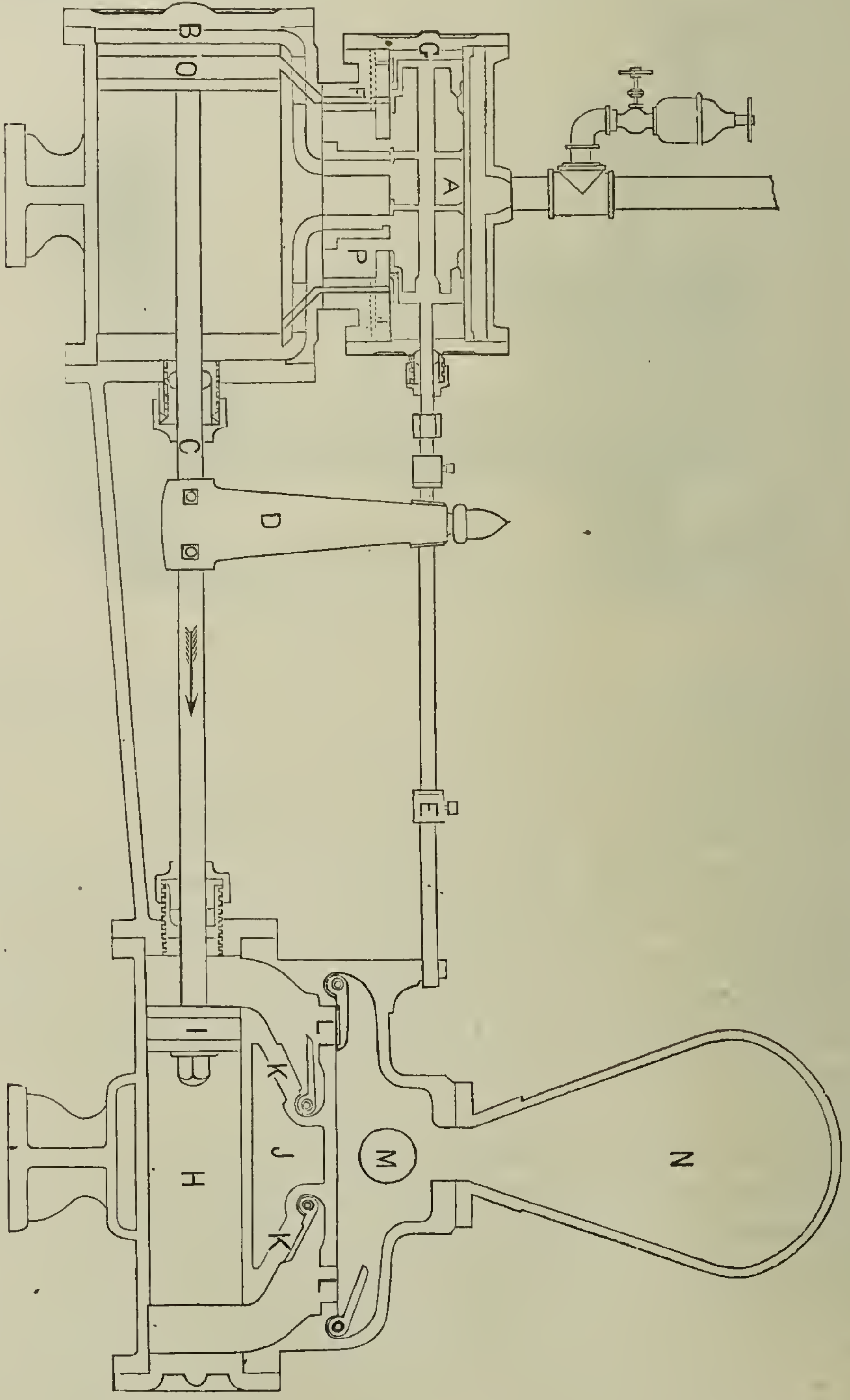


FIG. 80.—The Earle pump.

of pistons and other moving parts; a comparatively uniform flow of water, always in the same direction; adaptability to great depths, as a consequence of the fact that the rods are never submitted to a force of compression, and, further, absence of concussion, consequently permitting the adoption of high speed.

The point of cut-off of the engine is of course invariable, being originally determined by existing conditions which are quite invariable. In this case steam was expanded five times. The valves were "balanced" and actuated by steel cams. The condenser was placed directly beneath the steam-cylinder, and was annular in form. Two air-pumps were arranged, one on each side, working from the cross-head carrying the upper pump-piston.

The steam-cylinder was 24 inches diameter, (0.60 meter,) and had the same length of stroke of piston. The water-pistons had the same stroke as the steam-pistons, and were 10 inches (0.40 meter) in diameter. At 50 revolutions per minute, the pumps raise, together, 494½ cubic feet (14 cubic meters) per minute through a height of 24 meters (78.7 feet) with about 100 horse-power.

The whole apparatus is simple, compact, and effective, and did good work. The principal defect would seem to be the proximity of the condenser to the lower steam-cylinder head, and the consequent liability to absorb heat from it and to produce serious condensation of steam within the cylinder.

201. The ERSTE-BRÜNNER-MACHINEN-FABRIKS-GESELLSCHAFT established a set of pumping-machinery at the opposite extremity—the Western end—of the machinery hall, raising water, to supply the Exhibition, into a tank at the summit of a water-tower 150 feet high. The total lift was between 165 and 170 feet. The engines were Corliss engines, having cylinders 19¾ inches in diameter and 3½ feet stroke of piston. The pumps were double-acting, of the same length of stroke, and 12 inches in diameter. The same piston-rod carries steam and water cylinder pistons, the two cylinders being in line, the pump behind the steam-cylinder. These engines, when running at speed, made 22 revolutions per minute with a steam-pressure of 65 pounds. The engines are non-condensing. Speed is regulated by a hand-motion adjusting the cut-off apparatus. The exhaust passes through a feed-water heater. The whole of this work is creditable to designer and builders.

202. CENTRIFUGAL PUMPS.—The class of pumps misnamed centrifugal are now fully recognized as the most useful, and indeed the only kind which may be profitably used in elevating large volumes of water to moderate height.

Bucket or plunger pumps are not at all adapted to low lifts. The class here referred to excel them immensely in low first cost, in smallness of volume and of weight; even in efficiency the difference under the conditions here supposed is not great. Higher lifts and heavy pressure cannot be successfully met by centrifugal pumps, as the slip of the water through the pump becomes very great, causing a corresponding loss of efficiency; but under low lifts this slip becomes insignificant, and the advantages are all on the side of the centrifugal pump. In these pumps a rapidly-revolving axle carries a set of blades or fans, which force a stream of water, entering in the line of the axis, outward between the walls of the casing, into an annular or helical channel, from which a pipe leads it off wherever desired.

PRINCIPLES OF CONSTRUCTION.—It was supposed by Appold, the introducer of this class of pumps, that the effect was due to centrifugal force; but careful investigation has shown that the action is precisely that seen reversed in the turbine water-wheel.

The best form of fan or vane has been found to be that of which the trace on the plane to which the axle is vertical is a spiral, having proportions determined in each case by the height of lift and velocity of revolution.

The problem involved in designed water-elevators of this class may be stated in few words. The direction of the current passing through the machine and the direction of movement of the impelling surface should be so related at each instant that the force due to a change of motion of every particle from that of the normal to the direction of impelling motion shall be greater than that due to the actual change of motion proposed, and this relation should, further, be such that the work done in producing the actual change shall be the least possible. When those conditions are all fulfilled, every particle of the fluid, always taking the path of least resistance, finds that path which produces the required ultimate change of position with least expenditure of energy.

The form of the impelling surface and the path of the fluid particles are evidently peculiar in every instance, and are determined by the conditions of the individual case.

The proper form of the blades of the pump resembles the Archimedean spiral in sections taken in the plane of its revolution, and is approximately trapezoidal in its development on a plane passing through the axis.

The generally admitted advantages of these pumps are, that they are of small volume and weight, and at the same time have vast capacity under small lifts; they are of the simplest possible construction; their motion is continuous, and hence they are not liable to injury or loss of effect by shock; they elevate water containing small solid or semi-fluid bodies without difficulty; they are fairly economical of power, and are of very low cost, as compared with reciprocating-pumps.

These machines have an importance which does not seem to have been fully appreciated, and it has hence occurred that very few have been constructed correctly.

The principles of design are closely related to those involved in the design of turbine wheels. To secure maximum efficiency, the pump must be so formed and proportioned that the water shall enter it with

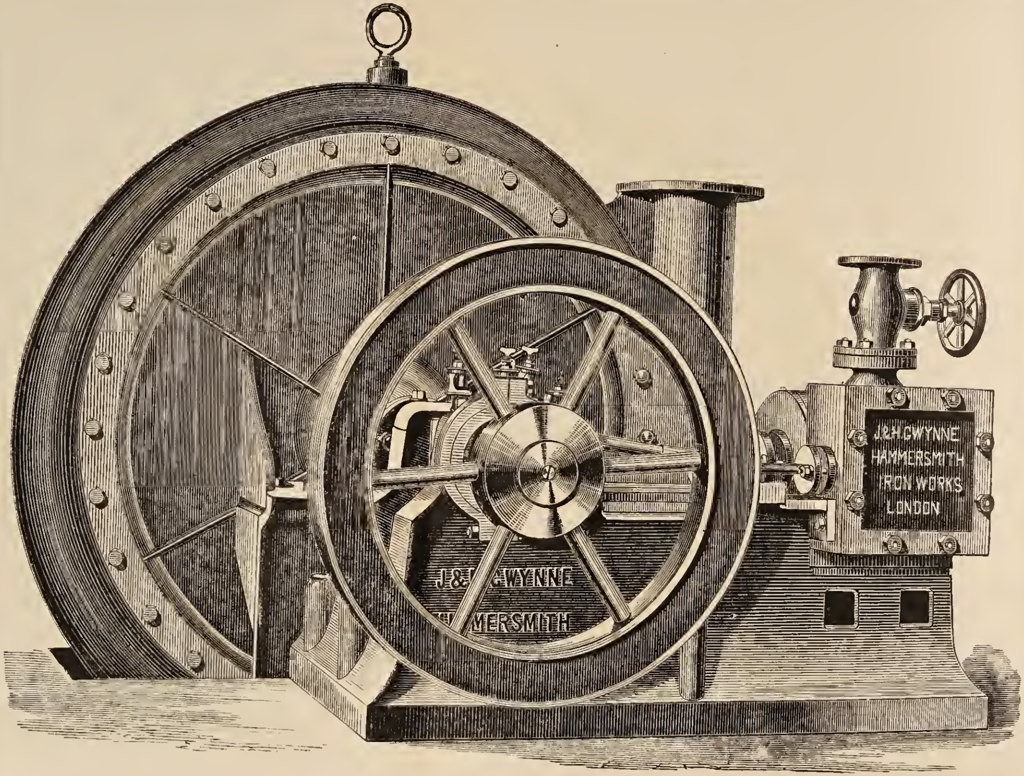


FIG. 81.—Gwynne's centrifugal pump and engine.

out shock; shall receive as nearly as possible a uniformly accelerated velocity; shall have the shortest possible path; shall make no sudden change of direction or velocity, and shall finally emerge into the delivery-pipe with a velocity somewhat exceeding that due the head of water incumbent upon it.

For a good form of pump, in which the interior radius is about 0.5 the exterior, the velocity of the circumference has been found to be satisfactory at 1.2 that due the height of elevation, and at the interior about 0.6.

As the velocity of the entering stream is obtained by suction, it cannot exceed that due the pressure of the atmosphere. It forms a part of head-resistance, therefore, equal in all cases to

$$H_1 = \frac{V_1^2}{2g_1}$$

and this must be added to the head H, under which the pump works. The maximum velocity is, therefore, that due to about 34-feet head, and is obtained when the pump is set at water-level. For any other case, the maximum velocity is reduced by the height of suction.

For excessive heights, the lift should be divided, and two or more pumps, set one above another, to re-enforce each other at regular intervals.

In laying out the form of the vanes, it is simply to be remembered that the path of the water is a resultant of the direction of motion of the water and of the pump itself, and that it must be made as smooth and direct as possible.

In construction, smoothness of surfaces, uniform variations in section of water-passages, accurate reproduction of the forms laid out by the designer, and ample bearing-surface in journals are the main requirements.

In operation, the pump should be driven smoothly and with perfect regularity at the speed best adapted to the lift. The pump should always be placed as low as possible, to reduce height of suction and to secure maximum delivery.

203. THE GWYNNE CENTRIFUGAL PUMP.—The most interesting collections of centrifugal pumps at Vienna were those of Messrs. J. & H. Gwynne, and Gwynne & Co., of London.

These pumps (Fig. 81) are built in large numbers by these firms. Both firms exhibit in their designs great strength, solidity, and neatness of proportions. They are claimed to be efficient under heads ranging up to 100 feet, and, in at least one instance, they have been actually used in the water-supply of a large town in two lifts under a head of 65 feet each.

J. & H. Gwynne cast their foundation-plate in one piece with the connecting-pipe and standard, thus securing greater rigidity and steadiness in working, and permitting the pump-case to be removed without disturbing the suction-pipes. This seems a comparatively cheap method of constructing also. The spindles are of steel running in bearings in which careful provision has been made for effective lubrication. The foundation-plate is moderately heavy. The motion of the pump is continuous, and, when well balanced, free from jar. It is, however, difficult to make the balance so perfect that, at the great speeds at which they are driven, they shall be entirely without shake, and a good foundation is desirable. For small sizes, two heavy beams are generally used to carry the pump. For larger sizes, brick or stone foundations should always, where possible, be provided. In soft ground, piles make a cheap and very good support.

These pumps have as few and as gradual changes of section in their pipe as can well be given. A change of transverse section always causes some loss. A sudden change in the area of cross-section is liable to produce a marked decrease of efficiency. The action of the pumps here referred to must be unusually perfect if, as claimed by their makers, the larger size will give satisfaction when set with a suction of 28 feet vertically. A very important requisite, ample width of driving-pulley, seemed to have been provided.

Several styles and sizes are made, in which the driving-engine and pump are on the same bed-plate. Such a combination finds many applications in ordinary engineering operations, and it is generally coming into use as a "circulating-pump" for steam-engines with surface-condensers. In this arrangement the engine is coupled directly to the pump-shaft without belting or other intermediate mechanism of transmission, and are given a somewhat greater diameter than would be considered best were it convenient to give the speed of rotation attainable where driving by belts. Some of these pumps are mounted on wheels for convenience of transportation. In one example, the axis of the pump coincides with that of the supporting wheels, and it can rotate about that axis, taking any position which may best suit the directions of suction and discharge pipes.

204. PUMPS AT FERRARA, ITALY.—The exhibitors first named have built a set of immense centrifugal pumps for the purpose of draining the Ferrara marshes of Italy, which cover an area of two hundred square miles, and from which they are expected to be capable of lifting 2,000 tons of water per minute to a height of 12 feet as a maximum. The mean lift will be 7¼ feet. Eight pumps are to do this immense work. They are arranged in pairs, each pair driven by a compound engine. The diameter of the disks of the pumps is 5 feet, that of the pipes 4½ feet. The casing is 15 feet in diameter. The driving-engines have cylinders 27¾ and 46⅝ inches diameter, with a stroke of piston of 2¼ feet. The cylinders are steam-jacketed. The cranks are so placed as to make an angle of 130° with each other. Surface-condensers are used of 750 square feet of cooling-surface each. Steam is supplied by ten boilers, each having 30 square feet of grate and 730 square feet of heating-surface. These are probably the largest centrifugal pumps and the most powerful set of pumping-apparatus ever constructed.

The senior of these two firms, Gwynne & Co., make not only the centrifugal pump, of which they are the original patentees, but very good gas-exhausters. Their merit was fully appreciated; they were given a high award by the jury.

205. Mr. J. Bernay, of London, exhibited a centrifugal pump, built from his designs by Messrs. Owens & Co., in which a passage is cut from the delivery to the suction leading through the shaft-bearings, and thus keeping the latter cool by the circulation of water through them.

The arms or vanes are carried between two disks which have a bearing against the sides of the casing along two rings, concentric with the axis, the intention of this arrangement being to prevent the usual loss of power from the friction of the liquid between side disks and casing by reducing the pressure there. The suction-pipe divides when it meets the pump, and the water enters at each side through orifices concentric with the axis, an arrangement now frequently adopted by other builders. This arrangement for keeping the bearings cool will probably be found very useful at such great speeds as are necessary with small pumps running under great heads. Under more favorable conditions as to speed, it will probably be found that the greater economy of power when the bearings are of good length, and well lubricated in the usual way, will be an important consideration, while, with proper proportions and good management, liability to heat need not be apprehended.

The arrangement for reducing friction between the surfaces of the disks and casing and the intervening layer of water by simply taking off all pressure will probably be found of less value than was anticipated, unless the experiments of General Morin, which indicated fluid-friction to be independent of the pressure, are less reliable than is generally supposed. The liability to severe grinding between the two metallic surfaces where contact is made, and at the great relative speed at which they run, is a somewhat unpromising feature. The slightest amount of gritty material passing through the pump would entirely destroy the smoothness of all rubbing-surfaces, and with bearings cutting and the disk grinding against the casing, the pump would be likely to be quickly injured beyond repair.

206. In the French section, the centrifugal pumps of MM. Neut et Dumont formed the most interesting collection. In these pumps, the vanes are in form more nearly in accordance with correct principles than were those of some of the other pumps exhibited. They were regularly curved from heel to tip, and were usually comparatively short. Four of them, however, extended to the axis, forming arms by which the whole set were carried. The water entered on each side, thus balancing horizontal pressures on this axis.

The arrangement for preventing the entrance of air through the stuffing-boxes of the shaft was quite neat, resembling somewhat the "lantern brass" of the steam-engines of a few years ago. A space is formed within the journal which stands full of water. Out of this space rises a small pipe which leads to the main pipe. Any air entering through the stuffing-box bubbles up through this small pipe instead of passing through into the pump. One of the most noticeable arrangements in this collection is that for great lifts, in which two pumps are used, the one re-enforcing the other. The water enters one pump and is driven by it into the second, which in turn forces it into the main under maximum pressure.

Dr. F. A. P. Barnard, in his valuable report on the machinery of the Paris Exposition of 1867, describes this arrangement as exhibited there by Coignard & Co., and calls attention to the fact that its successful application is a proof of the entire incorrectness of the idea, until lately entertained, that this class of pumps is dependent upon the action of centrifugal force for lifting-power.

The details of these pumps are unusually well considered. The driving-pulleys are covered with India rubber to prevent slip, as proposed in the United States by Mr. Sutton, of New York. The journals have large bearing-surfaces and are lined with anti-friction metal. The shafts are of steel, as are those of the best makers of other countries. The entrance of solid substances between the revolving disk and the casing is prevented, by properly-placed rabbets. The pumps seemed well proportioned and well made, and their builders have evidently succeeded in doing a large amount of business.

The experiments of M. Tresca show a useful effect of from 60 to 70 per cent., the former being the more usual results for moderate sizes, and the latter being sometimes reached with large pumps steadily working, as in supplying cities with water.

207. In THE COIGNARD PUMP the water enters a cavity which separates the two disks which the pump contains, and the current, dividing, enters at the middle or either side. The arrangement resembles somewhat a pair of the older sort, in which both disks are set on the same arbor. This double disk neutralizes the lateral pressure of the entering current, and this design also takes away all difficulties arising from the existence of shaft stuffing-boxes, where they may permit the entrance of air to the suction-side of the pump. The form of vanes is spiral, only two in number, and of considerable length. The water is not thrown out in the plane of rotation, but passes off laterally at the periphery of the disk into the main pipe. The current is thus divided from the moment of entrance to that of exit, and the designer claims to have succeeded in avoiding a considerable loss of energy which takes place in the other forms of pump in consequence of the collision of the double stream entering the pump and meeting at the center. The pump has given good results.

208. Messrs. NAGEL & KAEMP, of Hamburg, exhibited centrifugal pumps, with the turbines already described. The pumps raised water into reservoirs, from which the wheels were supplied. This pump was

the only one exhibited in which guide-buckets were used, the general plan closely resembling that of the turbine. The exhibitors claim a considerably improved performance as the result of this arrangement, but do not give reliable data relating to their performance. Messrs. Nagel & Kaemp do not use check-valves on the suction-pipes of their pumps, but fill them at starting by means of a jet-pump resembling somewhat the Giffard injector, an arrangement which is probably better than a leaky valve, but vastly more inconvenient and also more expensive than a simple float-valve, where the latter can be kept in good order.

209. THE SCHIELE PUMP.—In another design, the Schiele pump, also exhibited in the German section, the vanes or pallets are not fixed between two disks, but revolving unsupported except by the shaft, and the current of water is confined laterally by the casing of the pump. This plan would seem likely to cause unlimited trouble when pumping water laden with sand or other gritty material, which, entering between the vanes and the casing and cutting away both, would rapidly reduce the efficiency of the pump.

210. The most radical and perhaps most interesting departure from the usual form of the centrifugal pump was that of Messrs. BOULTON & IMRAY, exhibited in the British section. The shaft carries a cylindrical barrel, on the exterior of which is a set of straight vanes, quite closely pitched. This is set in a casing which, as the name indicates, is helical in form. The current enters the casing in a tangent line and follows a helical path, sweeping around its circumference and along the casing in an axial direction, crossing the orbit of the revolving blades which give it its motion, and finally emerges through a second opening, also tangent to the cylindrical casing. The action of the vanes or buckets is similar to that of the floats of the common steam-vessel's paddle-wheel. The general design bears some resemblance to that of the pump of Andrews & Brother, so well known in the United States. One of the important differences, however, is that in the latter the helix is also spiral, while in the former the line traversed by the current is at all times equidistant from the axis and is a true helix; the current enters and is discharged at the same distance from the axis. In this case the action is evidently a direct one, and the fact that centrifugal pumps are misnamed is well indicated by this simple illustration of the real action—that of pressure.

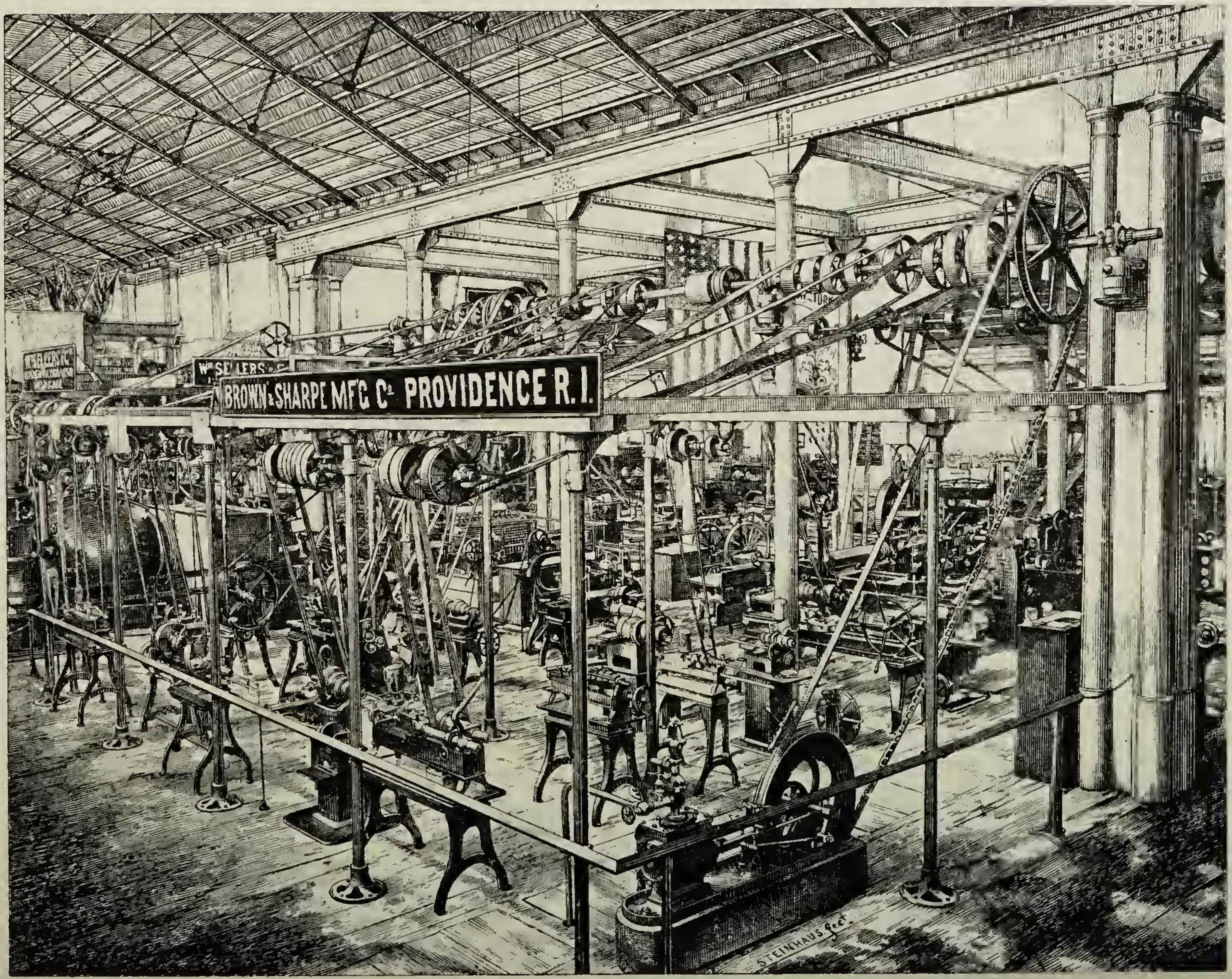
At Vienna this pump was driven by a three-cylinder steam-engine. It worked smoothly and well, but no statistics of performance were obtainable.

211. SPECIAL ADAPTATIONS OF THE CENTRIFUGAL PUMP.—The centrifugal pump, so called, is not capable of giving very high duty on even moderate lifts, and cannot compete in duty with those of positive action under such conditions. Its proper place is where low lifts and large masses of water are found. Here it does excellent duty, and in cases of

unexceptionally low lifts and great volume it even exceeds other forms of pumps in efficiency. Its low cost, its cheapness of "installation," its lightness and portability all combine to make it the only type of pump fitted for such work. Manufacturers of these pumps, however, are naturally exceedingly anxious to compete with builders of pumping-engines of other kinds, and vie with each other in the endeavor to secure contracts, even where the pump is quite unfitted for the work. As the duty given is too low to permit a reference to it in such cases, they usually avoid even its measurement, relying upon the real and undeniable advantages of the pump to secure its selection in spite of its lower efficiency. In very many cases, even where the lift is considerable, cheapness of first cost, portability, and compactness are more important than extreme economy of power and fuel. The centrifugal pump has, therefore, a wide field, and builders find a ready market for all of .the best designs, and they are now constructed in immense numbers.

There is evidently still room for improvement, but American builders are not behind foreign makers. Were the principles of the machine more generally understood, we might expect more rapid changes and much better results.

Vienna Exhibition 1873. Machinery etc.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CHAPTER X.

METAL AND WOOD WORKING MACHINERY.

METAL-WORKING MACHINERY AT VIENNA; EUROPEAN COPIES OF MACHINERY FROM THE UNITED STATES; COMPARISON OF BRITISH AND AMERICAN PRACTICE IN TOOL-MAKING; BRITISH AUTHORITIES ON AMERICAN METAL-WORKING TOOLS; TOOLS OF SELLERS & CO., OF PHILADELPHIA, THEIR LATHES, METHODS OF WORK, AND PRINCIPLES OF PRACTICE; LATHE-CONSTRUCTION; THE SPINDLE; THE CONE-PULLEY; WEIGHT AND STRENGTH OF SHAFTING; DESCRIPTION OF THE SELLERS GEAR-CUTTER AND SLOTTING-MACHINE; THE PRATT & WHITNEY COMPANY'S (HARTFORD, CONN.) SHAPER, PROFILING-MACHINE, MILLING-MACHINES, GANG-DRILL, REVOLVING-HEAD-SCREW MACHINE, ENGINE-LATHE, CUTTER-GRINDER, DIE-SINKING MACHINE, CHUCKING-MACHINE, PLANER, AND SPECIAL TOOLS; THE BROWNE & SHARPE MANUFACTURING COMPANY'S SCREW-MACHINES AND MILLING-MACHINES; THE STILES & PARKER DROP-PRESSES AND POWER-PUNCHES; BRITISH OPINION OF AMERICAN MACHINE-TOOLS; COMPARISON OF BRITISH AND AMERICAN METHODS; WEBB'S WHEEL-FINISHING MACHINE; OTHER BRITISH EXHIBITS; OPINION OF AN ARTISAN REPORTER; FRENCH METAL-WORKING TOOLS; SWISS TOOLS; OTHER EUROPEAN EXHIBITS; WOOD-WORKING TOOLS; GENERAL CHARACTER OF EXHIBITS; AMERICAN WOOD-WORKING TOOLS; B. D. WHITNEY'S PAIL-MAKING MACHINERY, GAUGE-LATHE, SCRAPER, BAND-SAW; RICHARDS, LONDON & KELLEY'S BAND-SAW; HISTORY OF THE BAND-SAW; HALL'S DOVETAILING-MACHINE, "SUDDEN-GRIP" VISE; J. H. FAY & CO.'S TOOLS; BRITISH WOOD-WORKING TOOLS; TOOLS OF RANSOME & CO., ROBINSON & CO., WORSSAM & CO.. POWIS, JAMES & CO.; FRENCH WOOD-WORKING TOOLS; PERIN & CO.'S BAND-AW; ARBEY & CO.'S PLANING-MACHINE; AUSTRIAN WOOD-WORKING MACHINERY.

212. METAL-WORKING MACHINERY AT VIENNA occupied a large part of the space appropriated to the United States as well as that of European countries, and it is in this department of industry that we observed the closest competition and the finest display of inventive talent and of mechanical skill.

The principal attraction to the professional visitor was found in the exhibits of the firms of Sellers & Co., Browne & Sharpe Manufacturing Company, Pratt & Whitney Company, and a few others from the United States; of Messrs. Sharpe, Stewart & Co., Ransome & Co., and one or two other British firms, and of Messrs. Duconun & Co., of France, all of whom exhibited machinery distinguished for strength, neatness of design, and excellence of material and of workmanship. These firms have also largely discarded the "high polish and deep scratches," which were once the characteristics of much of the work turned out by even the best houses, and have adopted the less flashy but far better tool-finish, which can now be so readily given by the standard machine-tools of the best builders.

There was a considerable number of exhibitors who displayed fine looking machine-tools, but they rarely gave evidence of originality in design, and a practiced eye and the hand of an experienced mechanic, who had been brought up in the recent school of American practice, detected readily the half-concealed file-marks and the inaccuracy of lines and surfaces, which proved them to have been built under a system which is out of date on our side of the Atlantic, and which would not be found had they been made by good machinery in skillful hands and finished with the tools which are now standard in form with us.

213. EUROPEAN COPIES OF AMERICAN TOOLS were seen in every section of the Exhibition. The more striking innovations made by our leading mechanics, where they had been previously exhibited at Paris in 1867, were almost invariably found to have been reproduced by European makers, and were exhibited at Vienna sometimes with, but oftener without, acknowledgment. Sellers's planer, with its peculiar cinematic combination of worm and rack, was one of these tools. The driving and the reversing mechanism were both seen on foreign copies, and the machines were sometimes placarded "*Système Sellers*" as an evident recommendation. Browne & Sharpe's tools were also copied, and all of the systems of sewing-machine combination were found, in *fac-simile* of American machines, among the exhibits of European nations.

It seemed the usual practice of continental firms to copy, with as great exactness as possible, the standard designs of British and American builders. In a few cases the copy was modified to suit the ideas of the copyist or to suit his market. Such cases, however, rarely exhibited success in the attempt to improve, and every departure from the standard design was, in most cases, an evident error on the part of the maker.

There were very few tools by continental makers which were nearly equal to those of the firms first above mentioned, and the advances made by the latter since 1867 were quite lost to the former. The tools now exhibited by our manufacturers are used as models in their turn, and form the starting-point for a new departure. A considerable number of American tools were sold to continental makers, and are probably to be copied at once for the European markets. The character of the work done by the firms named was fully appreciated by the members of the International Jury, one of whom, a distinguished authority in Europe, pronounced them "the leading constructors of the world." The tools most frequently copied were the Sellers planer, the Browne & Sharpe universal milling-machine, and the screw-cutting machine of the Pratt & Whitney Company.

214. BRITISH AND AMERICAN PRACTICE IN TOOL-MAKING differs somewhat, but each nation excels in some respects. The British builders put more metal and less ingenuity into their tools; while the American makers of tools are often distinguished for a combination of strength with lightness, and for a degree of ingenuity in adapting the machine to its work, which appears to the unfamiliar observer very remarkable.

The tendency, however, of practice on both sides the Atlantic is toward making heavy, strong frames, free from useless irregularities, and entirely without ornament of any kind; the finish is more generally given by the smooth cut of a well-formed and properly-adjusted machine-tool, and all parts are made to exact size and precisely alike, in duplicating for other machines, by the use of very accurate gauges.

The British practice of building their machinery so very substantially is one which every one admires, and, at first thought, approves, and yet it may well be questioned whether it is, all things considered, good policy in general work. In every branch of manufactures changes are continually occurring, and improvements are being made unceasingly. A time invariably comes when the owner of the almost imperishable machine cannot afford to keep it working, but must purchase a more modern machine, which will do the same work so much more cheaply that it will save its own cost in a very short time. The length of working-life remaining in the older machine, when it is thrown away to give place to the improved form of tool, is then representative of a certain amount of capital which is wasted. This loss is a very frequently-occurring one, but it is a more serious matter in new countries than among older and wealthier nations.

Where both capital and labor are plentiful and comparatively cheap and where ingenuity is not producing very rapid changes, machinery may and should be built more substantially and with a view to longer life than where labor and capital are held at a higher price, and where improvements are rapidly succeeding each other.

Within a few years manufacturers in the United States have learned that the only way to produce cheaply and to make their wares as excellent in quality as is demanded by the consumer, and yet to secure a fair profit, is to manufacture in considerable numbers machines that are precise fac-similes of each other in design and dimension. They have found it necessary to displace manual labor by machinery and to make every part to a standard gauge. Of this kind of work the sewing-machine and gun-making trades afford the best illustrations. The sewing-machine, which now costs the manufacturer $12 or $15, could probably not be made under the now obsolete system for less than $30, or perhaps even $40. The military rifle which is now placed in the hands of the soldier is made with equal economy. The benefit of this change inures to both producer and consumer. The former is able to manufacture and to sell in such large quantities and with so little incidental trouble and expense that his profits are larger in the aggregate than the amount of his capital could have produced for him under the old system. The consumer receives the product at a vastly lower price, and many people who could not purchase at all at the higher price cannot afford to decline purchasing at the lower cost.

In Great Britain there is less seen of this method of manufacturing, but the practice is gradually becoming established, and is now adopted by the more enterprising firms. They are not as well prepared, however, to profit by the advantages which it offers as their American competitors. They have less of that ingenuity and that originality which have become so well known as characteristic of our people, and which, encouraged by our excellent system of patent-laws, has enabled the latter to make such remarkable progress, and consequently their standard machinery usually lacked that remarkable elegance, symmetry, compactness, and fineness of tool-finish which is seen in the best work produced in the United States.

The standard tools of continental builders are such as were accepted standards among our own tool-makers a few years ago, and it seems to have been the fact, from the first, that, while closely following British and American practice, they are always somewhat behind them. Our method, of establishing standard designs and building in quantity, makes it a more serious matter to make a change than under the old system, which enabled the change to be made without incurring much additional expense, and this fact makes it more difficult for the continental builder to make such change.

When the European patent-code shall have been intelligently remodeled and brought into the form which experience in the United States has shown to be so efficient, and when European workmen shall have obtained such a social position and have received such a training that their ingenuity and their ambition and interest in their work shall have brought up the character of workmanship, as well as that of the workman, European makers may be expected to stand fairly beside their Anglo-Saxon competitors. It is of the same material that we make a large proportion of our workmen; the material is good, and only requires proper stimulus and training.

215. BRITISH OPINION OF AMERICAN TOOLS.—The merit of the tools exhibited in the United States section was fully appreciated and cordially affirmed by all foreign critics. London Engineering remarks:

"Machine-tools of all kinds form a very important section of the exhibits collected in the machinery-hall at Vienna, and there is probably no class in which the examples shown are so numerous. The number of instances in which real originality of design is shown is, however, far from being great, and where it does exist, it far more generally shows itself in the improvement of constructive details rather than in the introduction of machines of entirely new types. For the number of machines it includes, there is in fact no collection of tools in the Machinery-Hall which can compete for real originality of construction with that to be found in the American section. Setting aside the wood-working machinery, which we intend to treat in separate articles, we have in this section three chief exhibitors, namely, Messrs. W. Sellers & Co., of Philadelphia, Messrs. Pratt & Whitney, of Hartford, and the Browne & Sharpe Manufacturing Company, of Providence, all of whose exhibits will well repay careful examination.

"Messrs. W. SELLERS & Co., of Philadelphia, are well known as the Whitworths of America, and their exhibits at Vienna well sustain their reputation, both by their designs and the excellence of their workmanship."

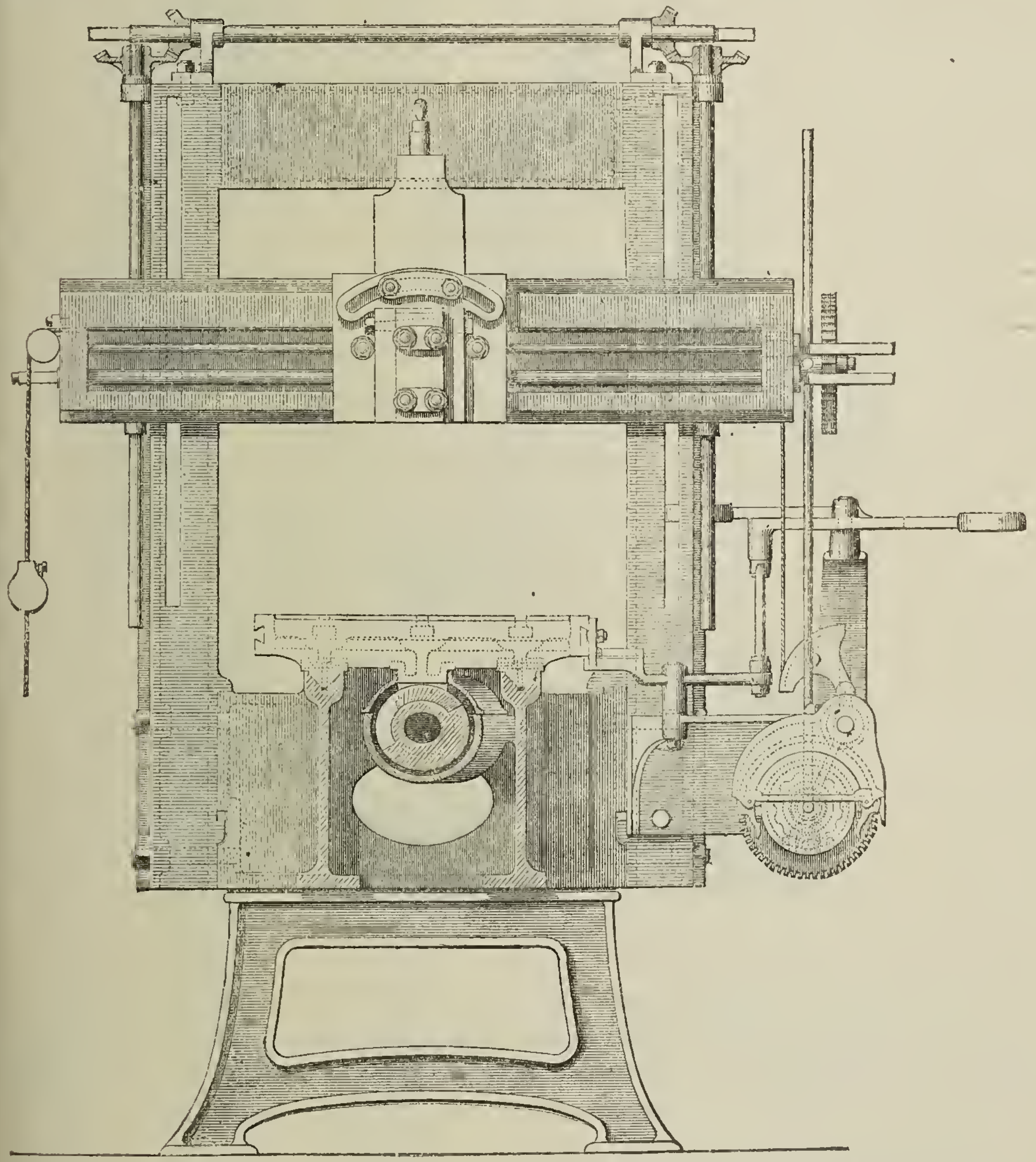


FIG. 83.—The Sellers planer—section of bed and driving-screw; elevation of cross-head and feeds.

216. The most striking and most important of the exhibits of Messrs. Sellers & Co. were their standard planer and their lathes, the new revolving puddling-furnace, a set of rolls, and one of their steam-hammers. They were all well placed and well exhibited, and were inspected carefully by every visitor at all interested in such subjects. Their neatness of design, simplicity of combinations, excellence of proportions in detail, and beautiful material and finish were unexcelled by anything found in Machinery-Hall. Comparing these machines with the copies found in

other sections, and which were intended to be fac-similes, the difference already alluded to between the practice of the two classes of machine-makers was seen in a very marked degree. It should, in justice to the latter, be said, however, that a few of the copies were very creditable pieces of work.

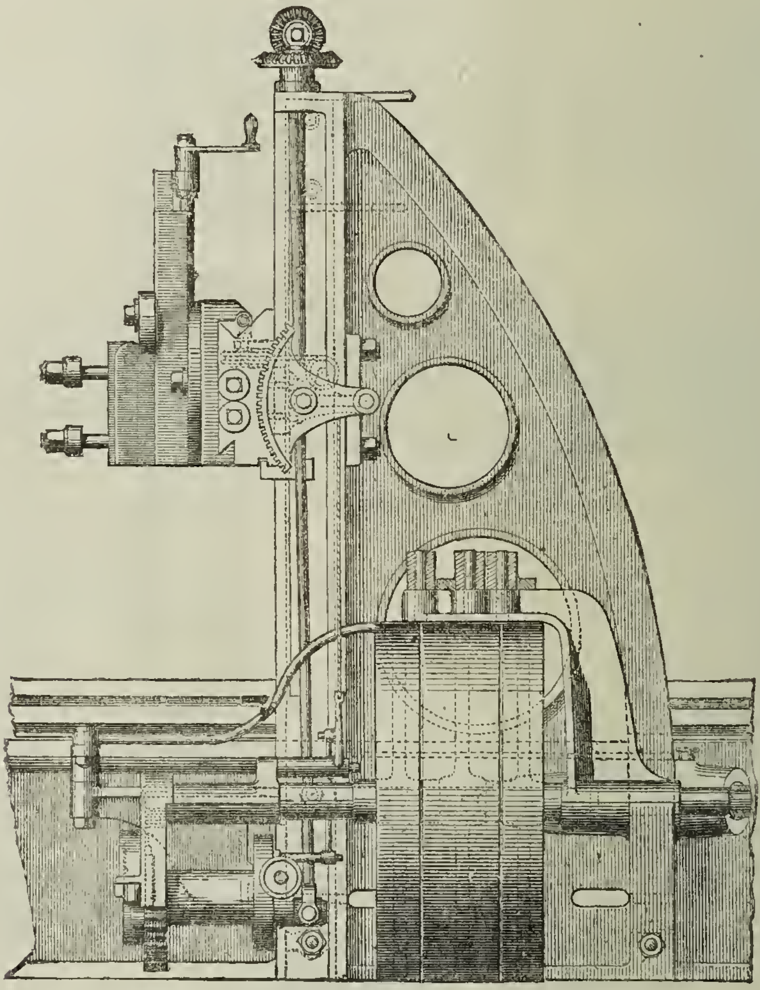


FIG. 84.—The Sellers planer—side elevation.

217. THE SELLERS PLANING-MACHINE (Figs. 83–88) is so well known that, were this report to be read only by tool-builders, it would be entirely unnecessary to describe it, but, for the benefit of the reader who is less familiar with its peculiarities, it may be advisable to describe it in some detail.

The frame, as shown in the figures, (83 and 84,) is of the usual general shape, but it is exceptionally neat and light, yet strong and rigid; the bed is solid and stiff, and the table is well arranged for the securing of the work upon it. The table is driven by a worm, Fig. 85, of which the axis extends diagonally across the machine, and which gears into a rack secured in the usual position beneath the table. The teeth of this rack are not set at right angles to its length, as is usual, and the inclination of its axis is such that the thread of the worm lies fairly between the rack-teeth. An examination of the cinematic action of this combination will show that it gives approximately a rolling contact, and that the friction and wear are consequently reduced to a minimum. This is

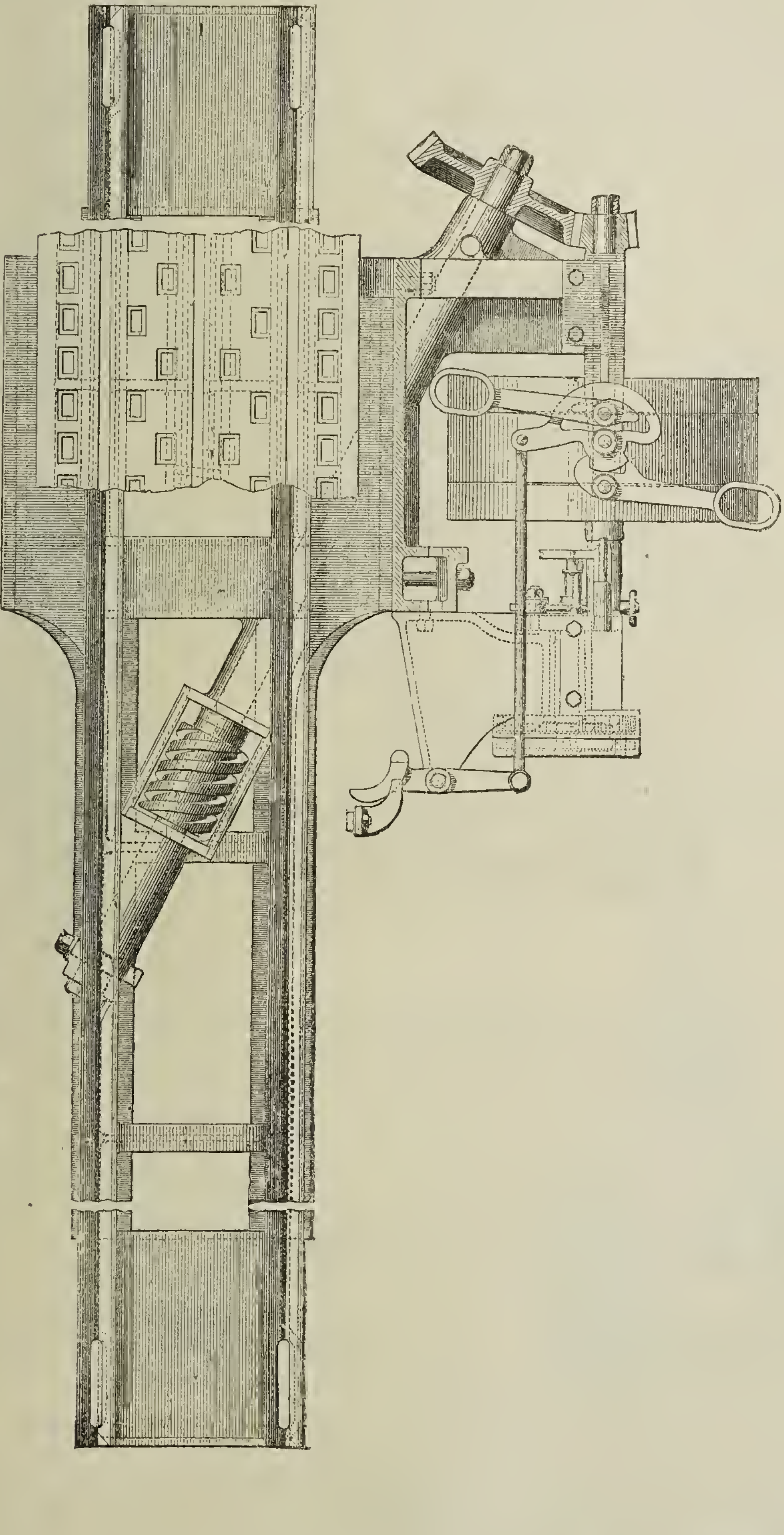


FIG. 85.—The Sellers planer—plan, table removed, showing the spiral gear.

well illustrated by a model shown the writer by the makers a considerable time before their appearance as exhibitors. It is this happy application of this geometrical combination that enables the makers to dispense with the trouble and annoyance incident to the lubrication of the driving-mechanism of the usual form of planer. The transmission of the motion of driving-pulleys to the worm-shaft is effected by bevel gearing so set that the shaft of the former lies in a line parallel with the side of the planer-bed. In the case of the planer driven by rack and pinion, the direction of this shaft is at right angles with the fore-and-aft line of the machine, and the tool must be set at right angles to the line of direction of the other kinds of tools in the machine-shop. The Sellers planer stands parallel with the lathes and is belted, and its counter-shaft is arranged as in the case of the lathe.

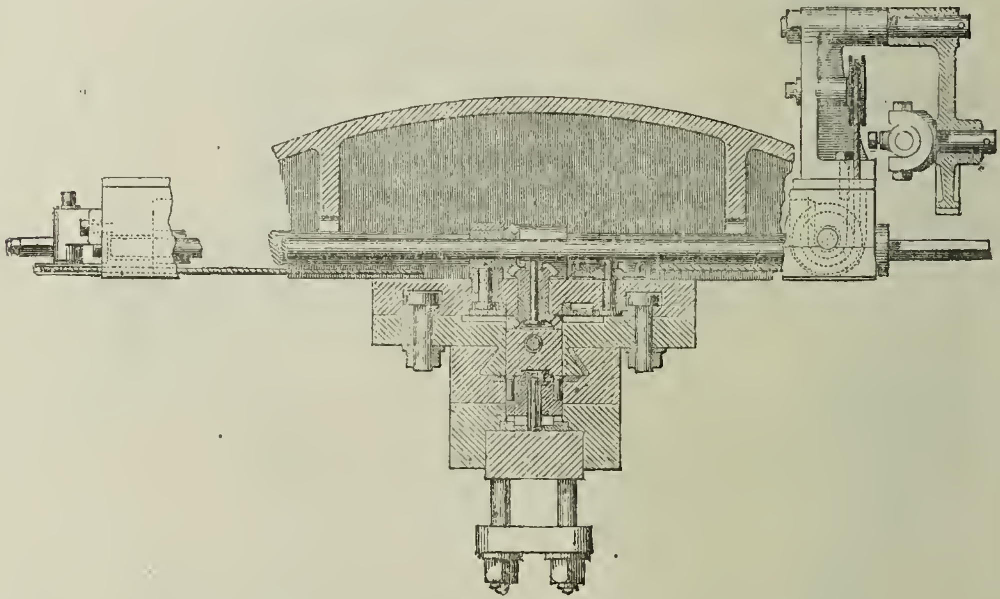


FIG. 86.—Section of cross-head and tool-holder.

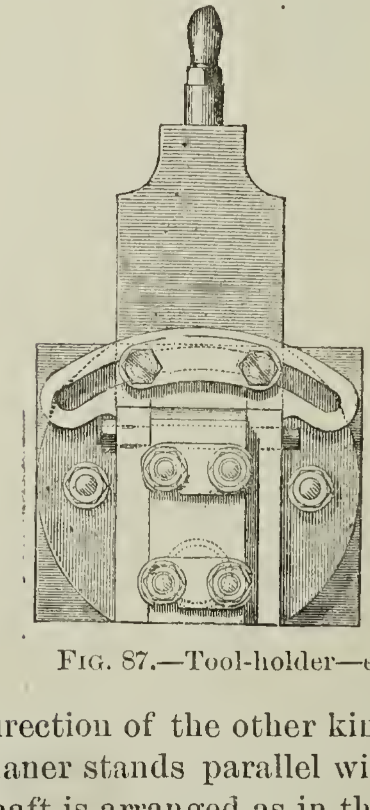


FIG. 87.—Tool-holder—elevation.

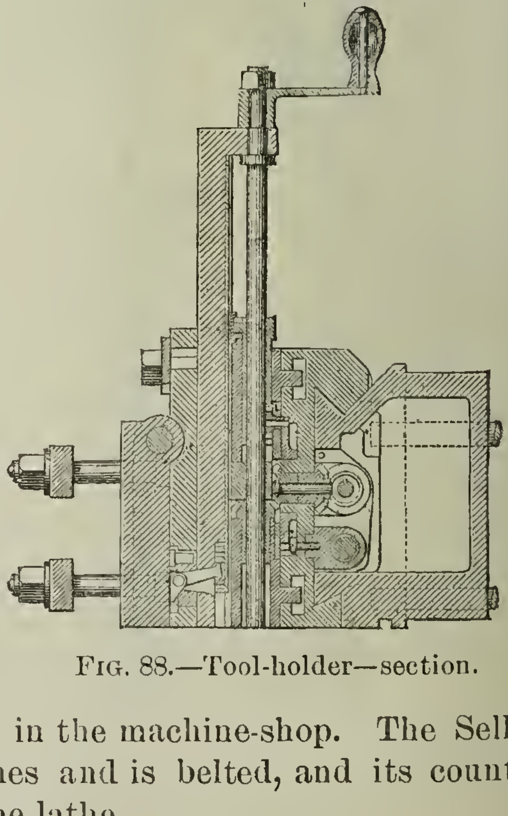


FIG. 88.—Tool-holder—section.

The belt-shifter acts upon the two belts alternately, throwing the driving-belt upon the loose pulley before the other belt is thrown into action. This is done in a neat and positive manner by the use of a sliding cam-bar. The arrangement saves a great deal of power, of wear and tear and loosening of belting, and the annoyance incident to the occasional catching of the table and halting at reversal.

The feed-motion, the methods of raising the tool on the return-stroke, and all other details are equally ingenious and effective. The tool only requires the addition of some such device as the Whitworth tool-holder, to enable it to do work on the return of the table, to make it in all respects better than the finest tool of its class known to the writer.

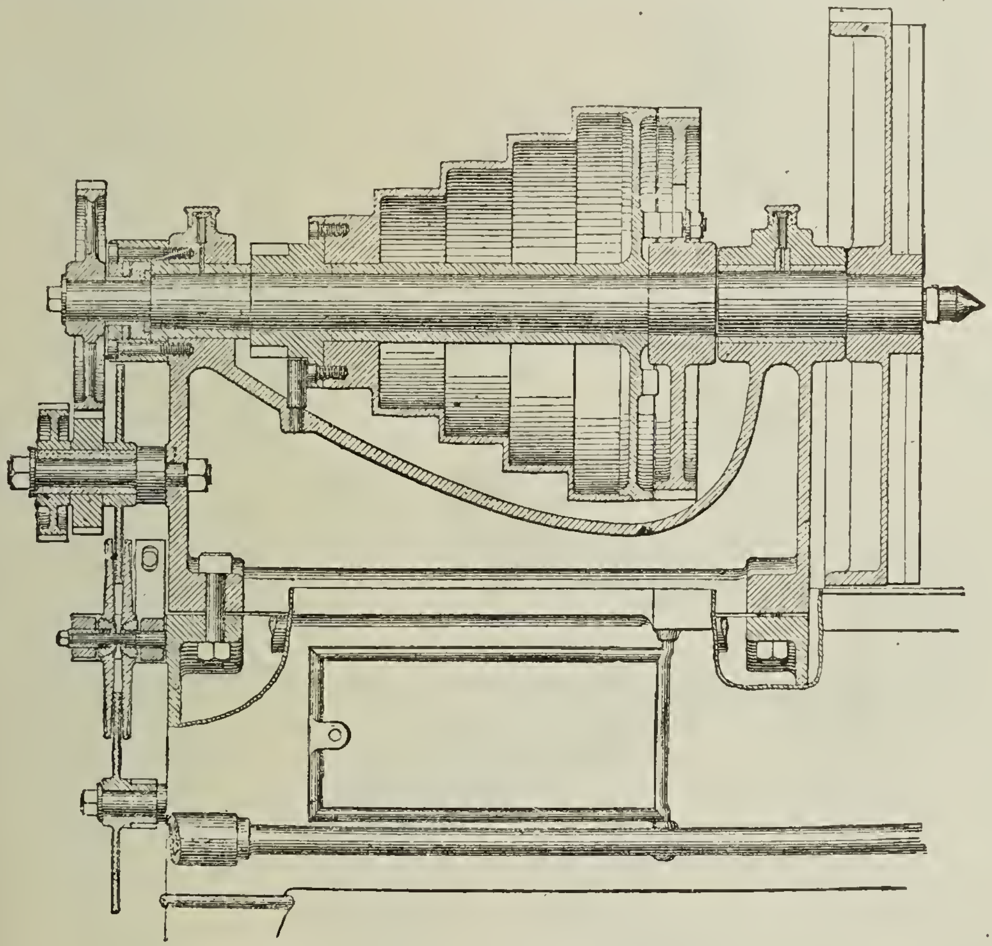


FIG. 89.—Sellers lathe-head—section.

The table of this tool affords the best illustration of the kind of machine-tool finish which has already been referred to. The final touch is given by a broad round-nosed planing-tool, with a coarse feed, and it is left smooth, neat, and absolutely plane.

218. THE SELLERS LATHE (Figs. 89–93) is another excellent example of the work of the firm. It is made strong and stiff by the character of the design, rather than by weight of metal. It has the same simplicity of form and neatness, without extravagance of finish, which characterizes the planer, and embodies some valuable peculiarities. The spindles are identical in form and size, and are ground to finished size in a machine built for the purpose, and in considerable

numbers at a time. They are, of course, interchangeable. The feed-motion is adjustable to any speed within certain limits, and with an accuracy which is only limited by the skill of the workman. The adjusting-mechanism consists of a set of mutually-acting friction-disks, and the adjustment is effected by altering, as is found advisable, the relative diameters of the circles of contact by means of a small handle provided for the purpose. The back-stock is fitted with a clamp, which draws it precisely to the center-line, even though a considerable amount of side-wear on the shears has taken place before it is secured down. The spindle is secured, when adjusted in contact with the work, by a clamp which takes on both sides, and thus does not tend to throw the dead-center out of line.

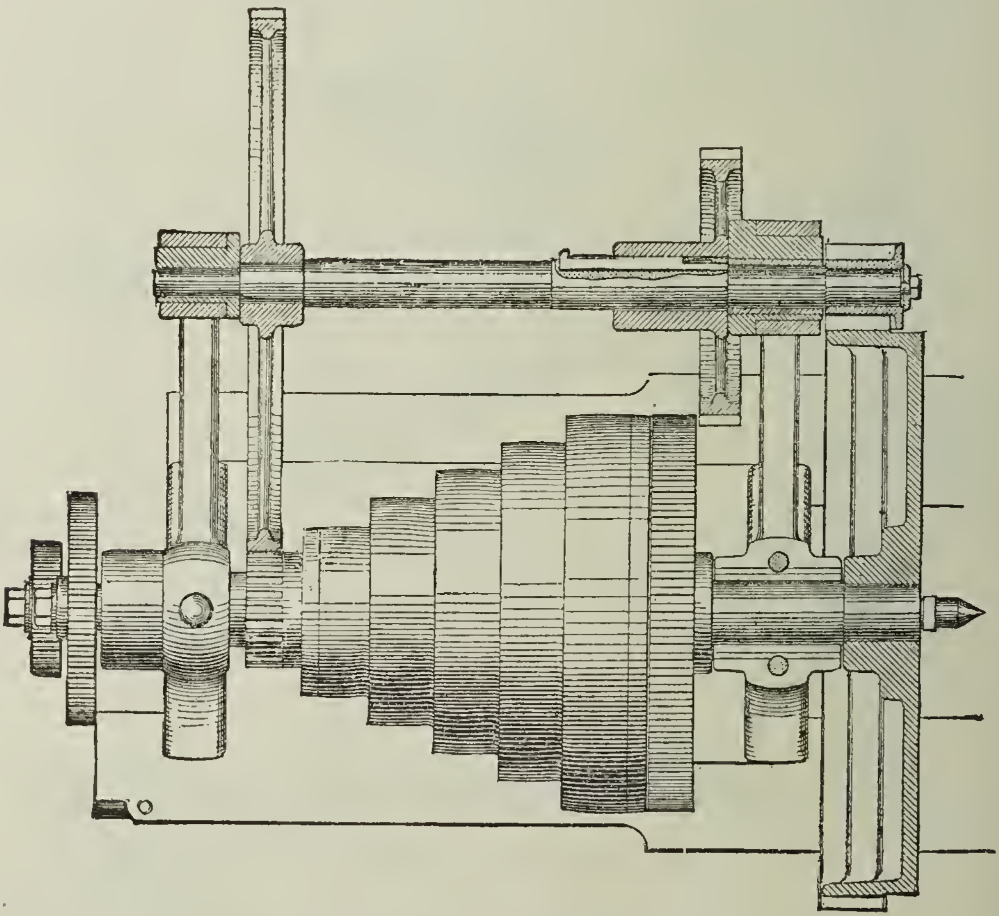


FIG. 90.—Sellers lathe-head—plan.

219. The 30-inch engine-lathe exhibited by Messrs. Sellers & Co. is illustrated in the accompanying engravings. It has, as is seen, the flat-topped bed, instead of the "shear" with V-shaped guides, a form which permits much less wear than the latter. Fig. 89 is a sectional view of the back-head, cone-pulley, and feed-apparatus. Fig. 90 exhibits the same part of the lathe in plan, and shows the back-gear in section. Fig. 91 exhibits the construction of the movable head-stock, with the device for clamping the spindle; and Fig. 92 shows the same parts in transverse section. The sides of the bed are connected by cross-girths at intervals of each 2 feet of length; these have an I-section, and extend from the base of the bed to as near the top as they can be carried

without coming in the way of the rest and back-head. Fig. 93 shows the construction of the compound slide-rest and its accessories, including longitudinal and cross-feed motions.

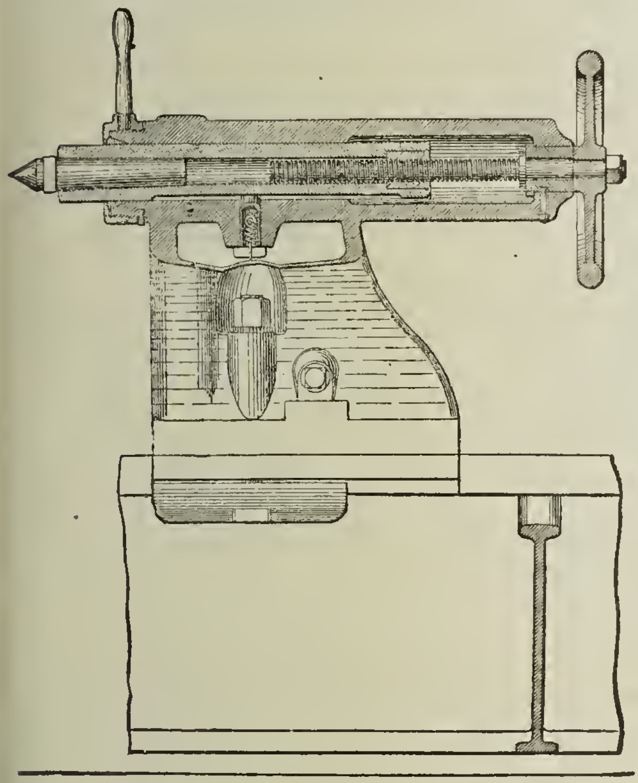


FIG. 91.—Sellers lathe—poppet-head.

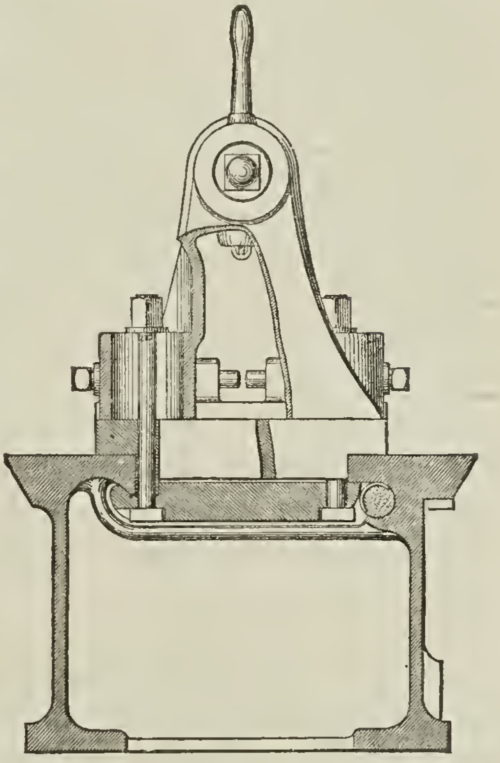


FIG. 92.—Sellers lathe—section.

220. THE PRINCIPLES AND METHODS OF WORK of the Messrs. Sellers & Co. are representative of those of our best tool-builders. They and others have effected very important improvements, within the last ten or fifteen years, by careful experiment and intelligent study of the

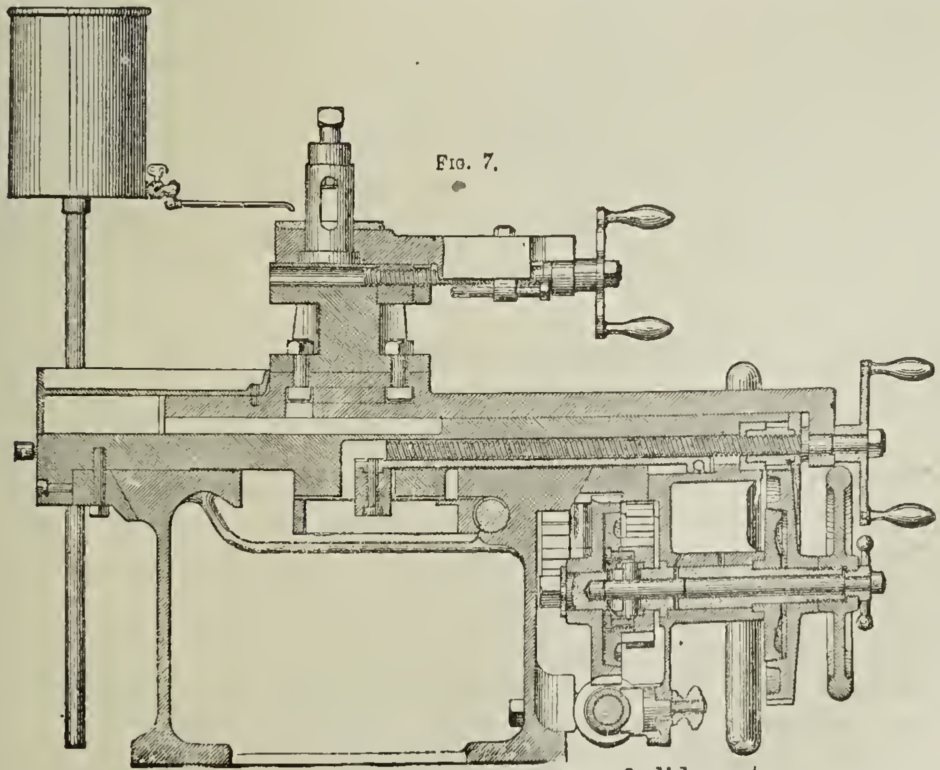


FIG. 93.—Sellers lathe—section of slide-rest.

problems involved in their constructions, and of the methods adopted in accomplishing their work.

To be able to produce a good lathe, it is necessary to know precisely what is demanded of this tool. It must be made as rigid as possible, to secure smoothness of cut and regularity of outline; it must be able to cut a perfect cylinder from irregularly-shaped masses, and it must be capable of producing a perfectly plane surface in the direction transverse to the line of the axes; it must do its work well, without liability to excessive wear, and must even do it well when old and worn. As these builders of our best tools themselves say, it is now necessary to furnish tools with which even inexperienced and untrained workmen, such as are too generally found in our shops, may do good work after very little training. This has a good result in two ways: it permits good work to be done where only unskilled labor is available, and it enables work to be done cheaply where skilled labor is only attainable at high prices, and thus permits the employment of untrained labor on routine work, and sets free skilled labor to attack work of exceptionally exacting character.

221. *The flat-topped bed* is always adopted by the Messrs. Sellers for the reason above given, and in this they have followed British rather than American practice. They say, in reference to their practice in this point, and in the distribution of the cross-girths, that they obtain very much greater nicety of adjustment and fit, greater wear, and very much more stiffness than can be secured in the older form of lathe shear built in this country, without introducing into the latter a great increase of weight of iron. The flat-topped bed gives much greater wearing-surface, and that surface is situated at right angles to the directions of pressure, and is, therefore, better prepared to resist wear; it is more easily finished and brought to size than the V-shaped bed; it gives less span between the points of bearing at the edges of the opening in the bed for the saddle of the slide-rest, permitting the latter to be made lighter or stronger than if fitted up in the other way; it gives a greater "swing," on lathes of equal size, over the slide-rest; this lightness makes the rest easier to move.

The method of clamping adopted with this bed permits a loose fit to be made where the back-head slides between the shears, and this insures less wear and less serious consequences from that wear. A V-shaped guide on the under side of the shear insures accuracy of movement for the clamp and precision in bringing the head into position. This they claim, with good reason, to be one of their most important improvements. The shear as made by these builders is very stiff transversely and in resistance of stresses tending to wrench or twist it, which stresses are the most serious influences tending to destroy the perfection of the work when the lathe is driven at high speeds, and when making heavy cuts. Such strains spring the bed downward and laterally, twist the spindles and the head-stocks, and strain the tool and the tool-post to an extent that is sometimes very serious. A lathe-bed of the form of a hollow cylinder, could it by any possibility be practically used, would best resist such strains. The common lathe cannot be thus mounted, and the form of the bed is largely determined by the arrangements of the several parts of the tool. The skill exhibited by our tool-builders in securing this required stiffness by the modification and arrangement of the bed and cross-girths is remarkably great. The broad flat-topped bed is incidentally useful, also, as a cover and to furnish support in carrying the lead screw along within it, giving it stiffness and exactness of line, and protecting very perfectly from the falling chips and from the dust which settles on all exposed surfaces.

222. *The lathe-spindle.*—As has been stated above, the spindles of these lathes are ground into proper shape, and are all made precisely to gauge. The importance of this method of manufacture will be understood when it is seen that the slightest looseness or irregularity of this little detail may destroy the value of all the labor and all the precaution taken in the making of the other parts of the lathe. If the spindle is irregular in shape, or ground "off center," it will produce a fatal loss of symmetry in the work.

In the Sellers lathes, and in the lathes of the Worcester School of Industrial Science and of some other tool-builders, the spindle is of steel, hardened and then ground into shape, and fitted into boxes of the same material, similarly brought to perfect size and form. With such spindles wear occurs very slowly with fair usage, and the lathe may run a very long time without the necessity arising for taking up play. A provision is, however, made for such adjustment. The bearing at the back end is made slightly conical, and loss by wear is taken up by simply moving it endwise in its bearings by means of the nuts provided for the purpose. The Messrs. Sellers take the end-thrust of the work on hardened and ground steel collars running between hardened and ground steel plates carried on the head-stock. They thus dispense with a "tail-screw," and are enabled to carry the spindle back and make it carry the change-wheels driving the screw-cutting feed.

The cone-pulley is turned, in Sellers' lathes, both inside and out, and is thus very nicely balanced; it is given a very long bearing on the spindle to insure freedom from wear. The changes are made by regular gradation. The arbor on which the pulley is carried is usually, except in very large lathes, of steel hardened and ground to size like the centers. The hole in the end to receive the latter is made with equal care and precision. The face-plate is not only carefully threaded to fit the thread on the arbor, but it is also nicely fitted with a plane bearing surface in the rear of the screw-thread, which insures perfect steadiness as well as absolute concentricity with the axial line of the spindles, even though the thread may become somewhat worn. A "former-attachment" is provided for turning tapers, &c.

223. *The weight of these lathes* does not seem to be as great

for similar character of work and in similar sizes as in some other makes, especially of English lathes, but it is evidently ample for their work. With their rigidity and strength, their few adjustments, and their excellence of workmanship, they permit an extraordinary amount of work to be done upon them in a given space of time.

The pulleys used on the counter-shafts are, like those on their main shafting, very light; but they are carefully proportioned and quite strong enough. They are made of selected iron, molded and cast under careful supervision, and are very symmetrical and are well balanced.

224. The shafting of Messrs. Sellers & Co. was a less generally observed but yet very interesting illustration of their peculiar practice. It was very light, carried light pulleys between bearings arranged in short spans, and the journals were of great length. It was driven at a speed greatly exceeding that of the heavier shafting used in other sections, or supplied by the authorities of the exhibition. Their couplings and their hangers were also in some respects peculiar, and contrasted singularly with the older and heavier styles seen everywhere else in the machinery hall. This method of driving machinery by means of light shafting running at high speed is essentially an American practice. It is seldom seen in Europe. In fact, the European methods of transmission of power have undergone very little change for many years. In mills, heavy gearing, running at slow speeds and carried on very heavy shafting, has been the rule. he expense of its manufacture is comparatively high; it is ill adapted to the high velocity-ratio required to connect it to the machinery of high speed, now more and more generally used; it is noisy, and it has many minor disadvantages. In the United States—instead of heavy lines of shafting and clumsy gearing, shafting 3 and 4 inches in diameter and wheels weighing from 100 to 500 or even 1,000 pounds—shafting 1¼ to 2 inches in diameter and pulleys of a few pounds' weight are found amply sufficient, and are in general use. Instead of speeds of 100 and 120 revolutions per minute, 250 is frequently seen, and in at least one instance the writer has seen shafting running at 450 revolutions per minute. With us the belted pulley has almost entirely driven out the older gearing. Even engines of 600 or 800 horse-power drive their loads by a pulley fly-wheel carrying three or four separate wide double belts. Power is a product of resistance into velocity; the first factor is expensive, the latter inexpensive. Increasing the former and reducing the latter means greater weight, increased first cost, and greater expense of maintenance of the machinery of transmission. The converse practice brings in light machinery and reduced expense. The "telo-dynamic" method of transmission of power, which has been introduced on both continents, is simply an illustration of the same principle carried still further for special purposes.

In the manufacture of shafting, the higher speeds and the light pulleys and belting now used have greatly reduced the first cost where the power transmitted is the same. The system of manufacture now standardized in the United States and practiced by the Messrs. Sellers is the same as that which distinguishes the sewing-machine business. All sizes are determined by gauge, and the shafting and pulleys are made in quantities for the general market, instead of to special order, and of various sizes. This also lessens the price in a very important degree.

The sizes were determined after an elaborate series of experiments, and were made standard, and the shafting was then sold by a schedule in which the weight was not given but sizes and power were stated, and a guarantee was given of their fulfilling the requirements of the purchaser.

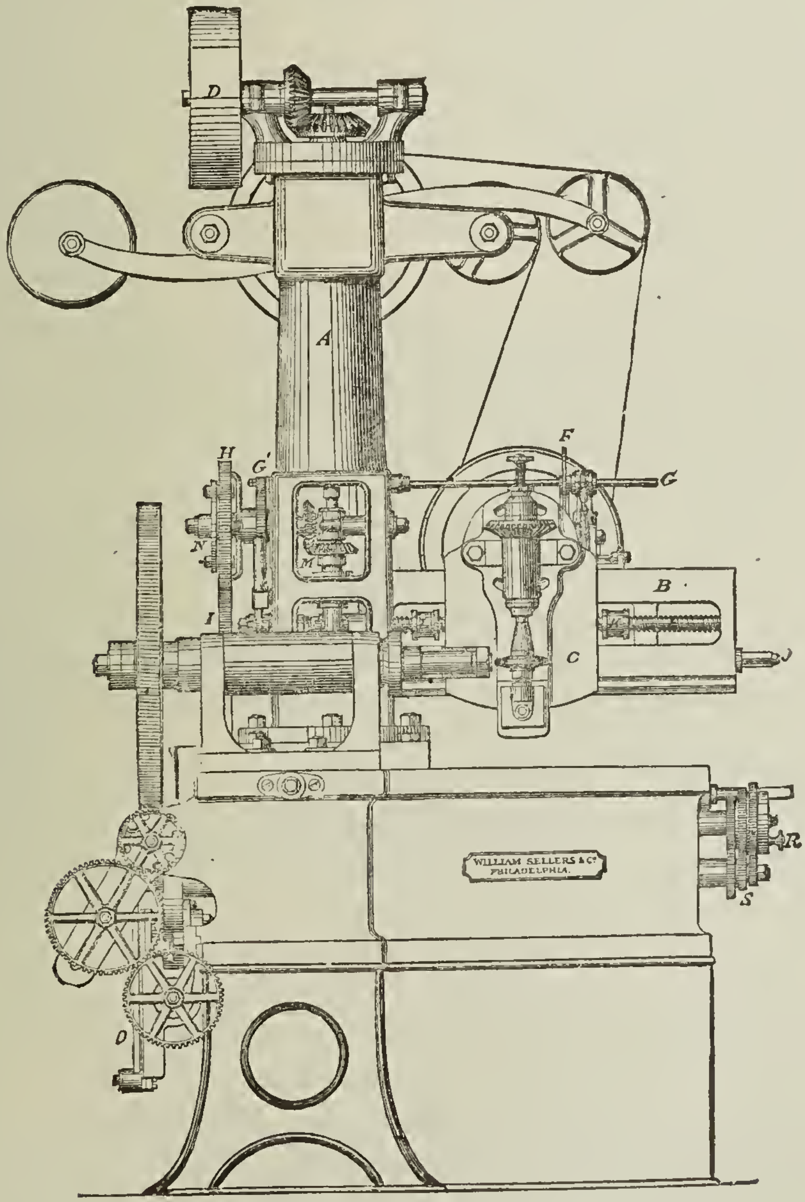


Fig. 94.—The Sellers gear-cutter—front elevation.

The Bancroft hanger, as improved by the makers, is used with the shafting. Its journal is so mounted that it may swivel in all directions and accommodate itself perfectly to the line of the shafting, however great the departure from its proper location. Some slight variation from the correct line is usually unavoidable, and it introduces frequently a very serious addition to the power required to drive the shafting.

225. THE SELLERS GEAR-CUTTER.—A very beautiful and ingenious gear-cutting and wheel-dividing machine was exhibited by Messrs. Sellers & Co. This machine is arranged for cutting both spur and bevel wheels, has a capacity up to 54 inches diameter of wheel, 9 inches face, and will cut a number of small spur-wheels of same size at one time. It is entirely automatic, performing all its work after adjustment, without attention of workmen, to the completion of the wheel being cut or divided. The division is obtained by a tangent-wheel and worm carefully constructed. The turning of the handle and all other motions are done by the machine itself. Thus, a blank wheel being put in place, and the proper cutter adjusted to depth of teeth, length of stroke of cutter-head, &c., the cutter will pass across the face of the wheel, cutting the space between two teeth. It will then return quickly to the starting-point. The blank will then be turned to present a second space to be cut, and the cutter will automatically start again. One machine is said to do one and a half times the work done by a skilful workman on a gear-cutter operated by hand. In practice, one man can attend to four of these machines.

Fig. 94 is a front elevation and Fig. 95 a side elevation of the machine. An important feature in this machine is that the various movements required to do the work follow each other automatically in regular sequence, each one being dependent on the completion of the motion which preceded it.

In the figures the machine is shown as arranged when cutting spur-gearing. The post, with its projecting arm carrying the cutter-head c, is made to swivel between its base-plate and the cap which carries the driving-pulley, so as to set the arm either parallel to the axis of the wheel to be cut for spur-gearing or at an angle for bevel-gearing. It is adjustable to any required position on the bed. Motion is conveyed to the cutter-head spindle from the pulley by means of bevel-wheels to the cone-pulley at the top of the post, and thence by belt over guide-pulleys (one of which acts as a tightener) to the cone-pulley back of the cutter-head, thence by bevel-wheels to the spindle. The cutter-head slides back and forth on the arm, driven by a nut on a screw. This screw is stationary, the nut only revolving, and the train of gearing which moves the nut or causes it to revolve starts from the lower cone-pulley by bevel-wheels, through a set of variable friction-disks, to a shaft, and by a pinion through a sun-and-planet system of wheels to a gear-wheel on the end of a shaft, which passes through the arm below and parallel to the screw, which shaft terminates in the square end. Spur-wheels convey motion from this shaft to the revolving nut. Upon the screw are two nuts which are adjustable on the screw, and are readily clamped at any required position. These two nuts determine the length of stroke of the cutter-head. By means of a crank on the end of the screw within the post, the turning of the screw one way or the other through a small portion of a revolution operates clutches within the post, which determine the requisite motions of proper sequence. Thus, the screw being stationary during the travel of the cutter through the wheel, the revolution of the nut on the screw causes the advancement of the cutter-head toward the nut. When the revolving nut comes in contact with this stationary nut, a tooth in the revolving-nut engages with a tooth on the stationary nut, and turns it and the screw, and as both nut and screw revolve in the same direction at the same time, the forward motion of the cutter-head ceases and the rotation of the screw operates the device that is to start the next motion, *i. e.*, the running back of the cutter-head to its starting-point. Here it again comes in contact with the nut, ceases its lateral motion again, and imparts a rotary motion backward to the screw, stopping the driving-machinery last in motion and putting in motion the machinery that turns the blank. The completion of this last operation starts the cutter into the work again. Through the center of the column is a vertical shaft, which revolves continually in one direction. The bevel-wheels are held from turning,

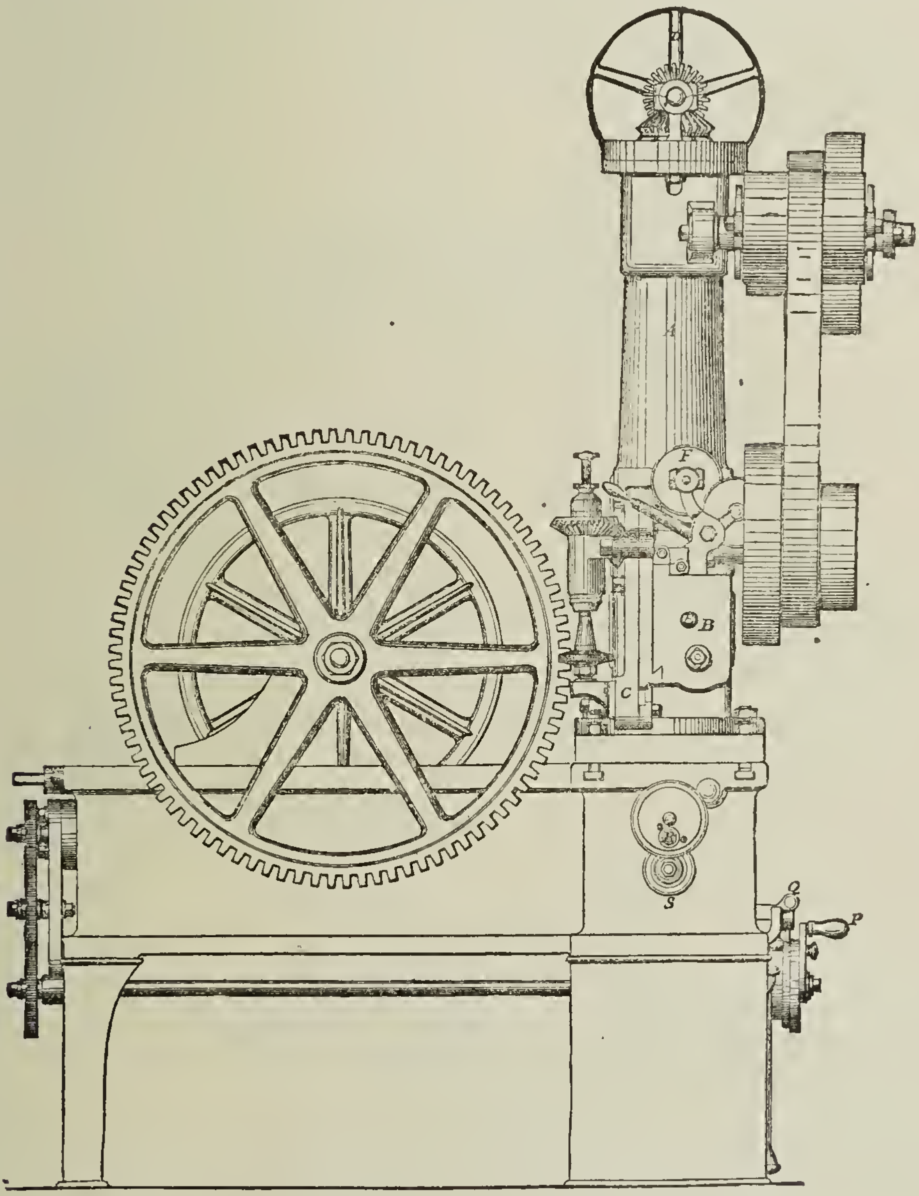


FIG. 95.—The Sellers gear-cutter—side elevation.

allowed to run loose, or are driven by the vertical shaft, as may be required. The planet-wheels are attached to a face-plate, this face-plate to one of the bevel-wheels. When the bevel-wheels are held stationary the sun-wheel in the center drives the outer wheel and the feed. If the bevel-wheels run loose, the feed stops.

THE SELLERS SLOTTER.

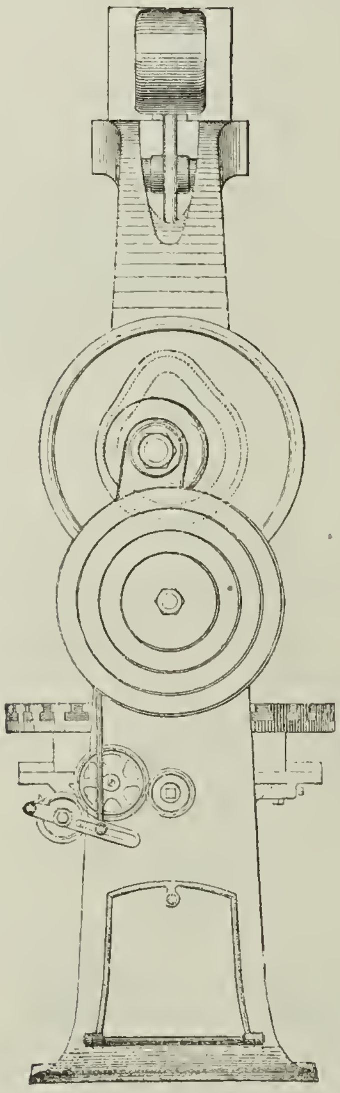


FIG. 96.—Rear elevation.

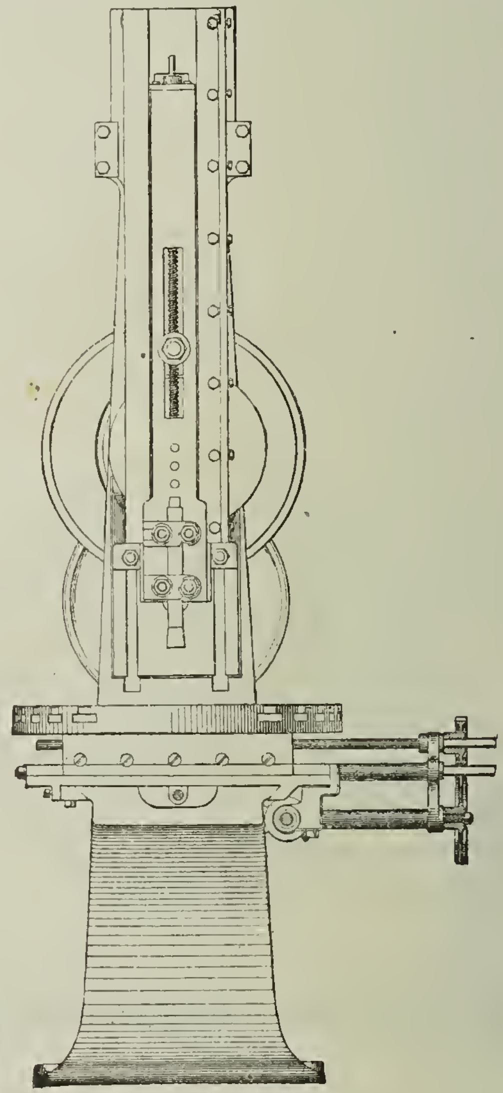


FIG. 97.—Front elevation.

If a rapid rotation be given to the bevel-wheels, they will drive the planet-wheels around the center one, and thus impart a rapid motion to the nut on the screw to carry the cutter back to its starting-point; but when it has reached this point, the wheels are cut loose from this driver, machinery is put in motion within the bed, that, by means of a crank, rack, and pinion, turns the crank-handle, lifting the latch at each revolution. The number of turns of this handle are determined by a pin being placed in one or the other holes shown in the face-plate that controls a nest of gearing. A cam on a shaft within the bed, upon the completion of the proper number of turns of the handle, moves the clutch to clamp the bevel-wheels, and thus starts the feed once more.

This completes the series of operations. Any one of its individual motions may be lengthened or shortened, and yet not affect the others. The failure of any one to act merely prevents the next one from starting, so that no harm can be done the work.

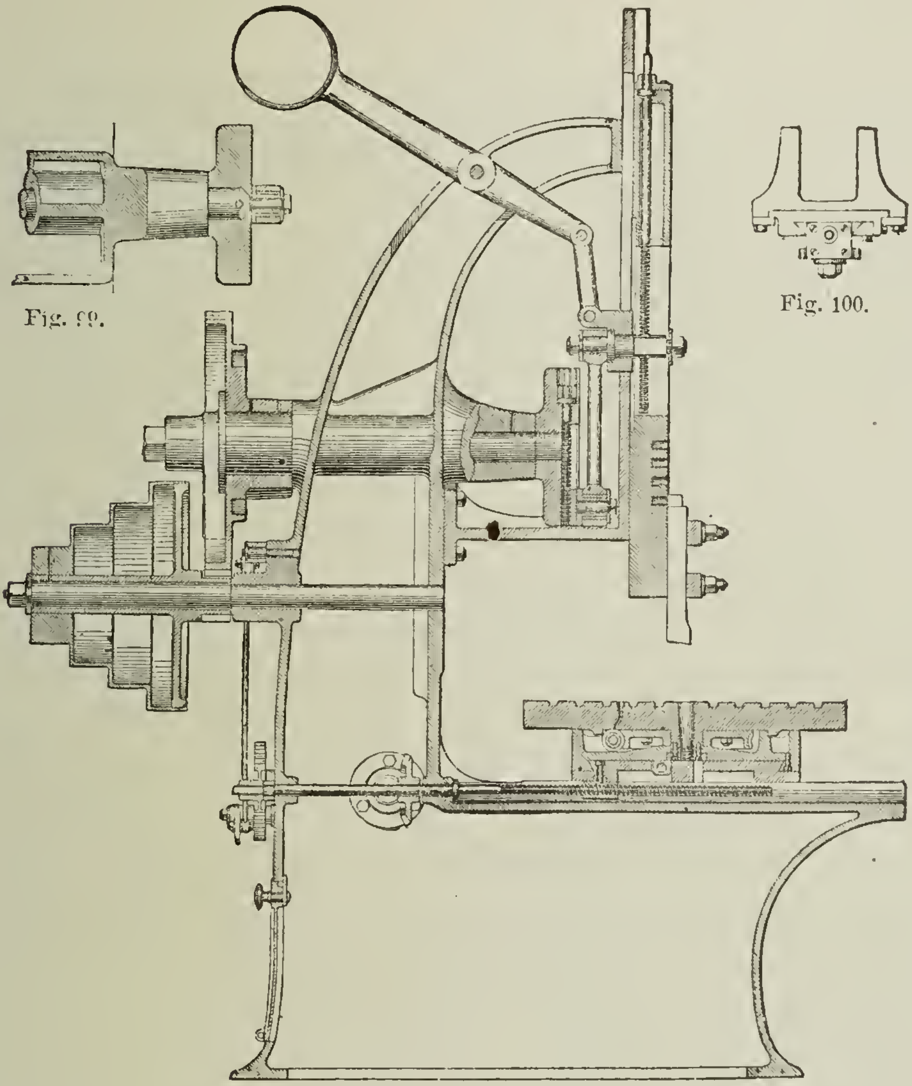


Fig. 99.

Fig. 100.

Fig. 98.—Section.

226. The Sellers slotting-machine.—The Messrs. Sellers & Co. exhibited a 48-inch slotting-machine, (Figs. 96–100.) The slotting-tool is operated by means of a crank driven by the "Whitworth motion," giving a slow movement when cutting and a quick return. The crank is adjustable in length of stroke, the maximum being 12 inches. This adjustment is effected by a screw in the crank-plate. The adjustment of the connection of the connecting-rod with the slotting-bar is obtained by means of a screw, regulating the position of the slotting-bar in height from the table upon which the work rests.

The connecting-rod is attached to the slotting-bar by means of a wrought-iron block connected with a counter-balance-lever. The counter-balance is heavier than the slotting-bar and cutting-tool, so as to take up all lost motion and to steady the operation of the machine under cut. The bearing or slide carrying the bar is adjustable for different heights of work. When the nature of the work will permit, the supporting bearing can be carried quite close to the table, thus giving a firm backing to the tool during its whole stroke and insuring steadiness of motion. The compound table upon which the work is bolted consists of the usual slide-rests with a rotating-table on top of the upper rest, all provided with automatic feeds. An important feature of the machine is the arrangement of its feed-motion, which insures the feed always occurring at the top of the stroke, and never during the cut. The great advantage of this is manifest when it is remembered that should the feed occur at lower end of stroke, the rigid tool will drag back with a pressure due the amount of feed. The working-handles to operate the feed by hand are, on all these machines, within easy reach of the workman, and in such a position as to enable him to readily see the point of the slotting tool as he adjusts the feed, an advantage readily appreciated when the machine is used to slot to scribed lines.

227. The Pratt & Whitney Company, of Hartford, Conn., had an exhibit which, although somewhat less extensive than that of Messrs. Sellers & Co., was very interesting, and was reported upon by the International Jury in terms of exceptional commendation. Their tools were a light class of machines, intended for gun-makers and for similar light work. They were remarkable for their excellence of design; each was beautifully adapted to the special work which it was intended to do; the material and workmanship were of the highest class, and the finish was neat and appearance pleasing.

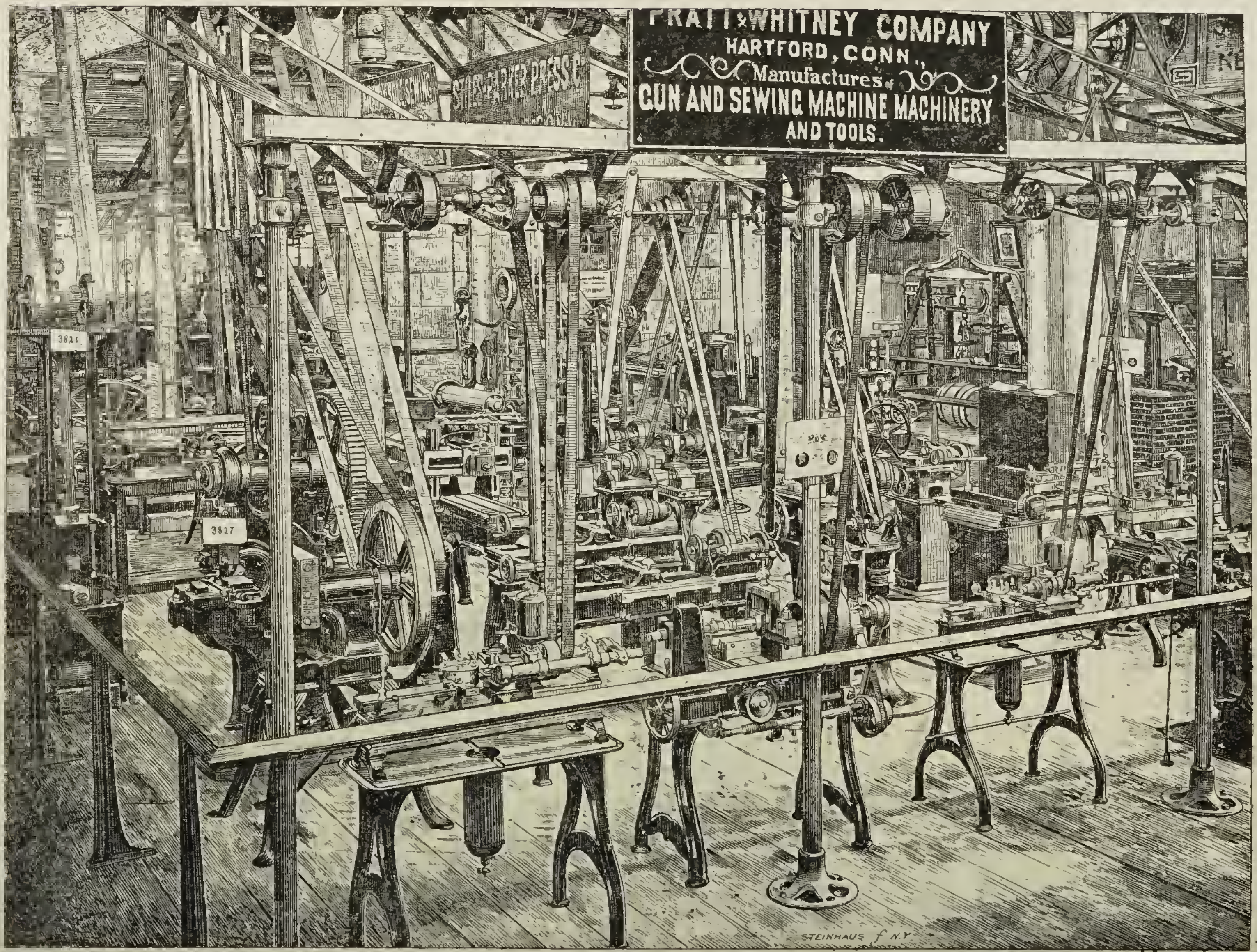
Their screw-machines had already attracted the attention of continental dealers, who had had opportunities of seeing them in several governmental and private European establishments. This firm have for some time supplied their tools to foreign markets. In the screw-machines the rod of which the screws are to be made is clamped in the hollow spindle of the machine, and the dies are mounted on a "turret." The several cuts are rapidly made, the workman setting the bar in position, clamping it by a single movement of the handle operating the chuck, throwing up the turret into position by another motion, and then, setting his machine in operation, a cut is made. The reversal of this succession of movements releases the screw after the cut is made, and a second cut is then taken, the turret being turned so as to bring the next die into action. A cutting-off tool is mounted on the slide-rest, with which the screw is separated from the bar when completed.

The chuck-lathe made by this firm is a very neat, simple, and effective tool for use in turning pieces to peculiar form or for boring them out. Their drills are also of designs original with them, and very excellent tools, and their milling-machine, although not having the wide range of adaptation of the Browne & Sharpe machine, is an exceedingly well-designed and well-made tool, and is even better adapted to general use on plain work.

228. *Descriptions with Illustrations.*—The Pratt & Whitney Company's machines are illustrated in the accompanying engravings.

Vienna Exhibition 1873

Machinery etc.



American Photo-Lithographic Co. N.Y. (Osborne's Process)

The ten-inch pillar-shaper (Fig. 102) is also known as the "compound Planer," and, in a large proportion of cases, it is a substitute for the ordinary and expensive shaping-machine. It is particularly well adapted to die-work. The stroke may be graduated to any point within the extreme limit; the tool-bar has a quick return, and the cross-feed is automatic and adjustable. The designation indicates the extreme length of stroke, which is, in this machine, ten inches. All the slides and bearings are fitted carefully by scraping, and the nuts, screws, and wrenches are hardened. The Newell patent vise is exhibited with the machine. It is intended for holding the work, and has a circular graduated base, and hardened-steel-faced jaws, ground true, one of which "swivels," to present either a straight or a V-shaped slide, the latter for holding circular work. The machine stands on a hollow column, the base of which measures thirty-six by twenty-seven inches, as shown in the figure.

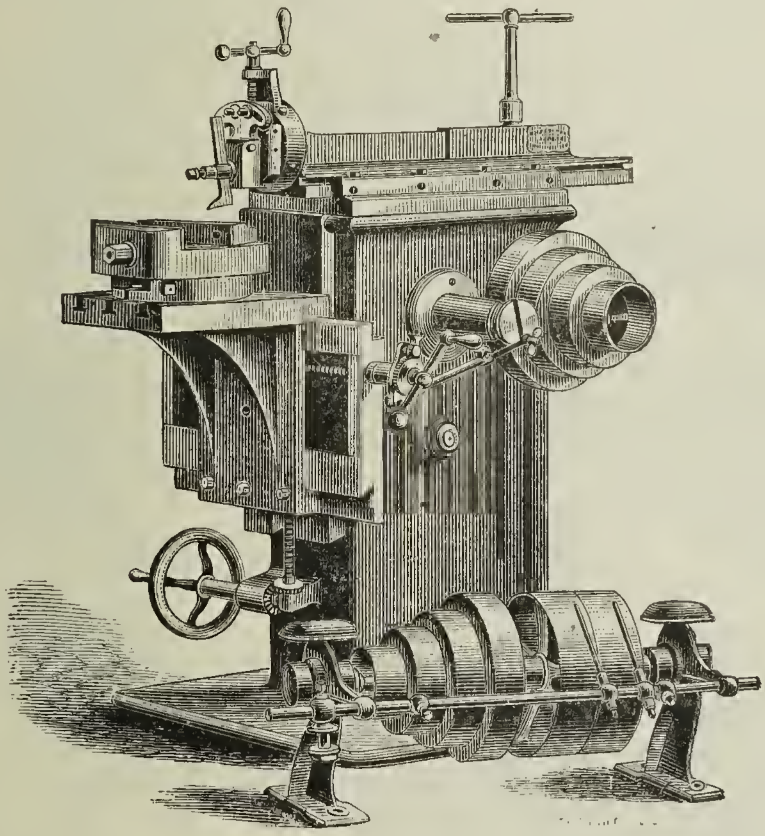


FIG. 102.—Ten-inch pillar-shaper.

229. The profiling-machine is a well-known and highly-valued tool for cutting irregular forms. The one shown in the engraving (Fig. 103) is a two-spindle machine, and has Parkhurst's patent device for cutting forms without reversing the fixtures. With this improvement, to produce the forming-pattern, the model-piece is secured in the place and position afterward occupied by the work to be "machined," and the piece to be cut for the forming-pattern is placed in the position it will permanently retain. The guide-pin is put in the spindle which usually carries the cutter, while the cutter in the spindle which afterward holds

the guide-pin cuts the pattern in the exact position it will retain in use. After disconnecting the gearing upon the spindles, reversing the relative positions of guide-pin and cutter, and smoothing the edge of the forming-pattern, (if this be necessary,) the machine is ready for work.

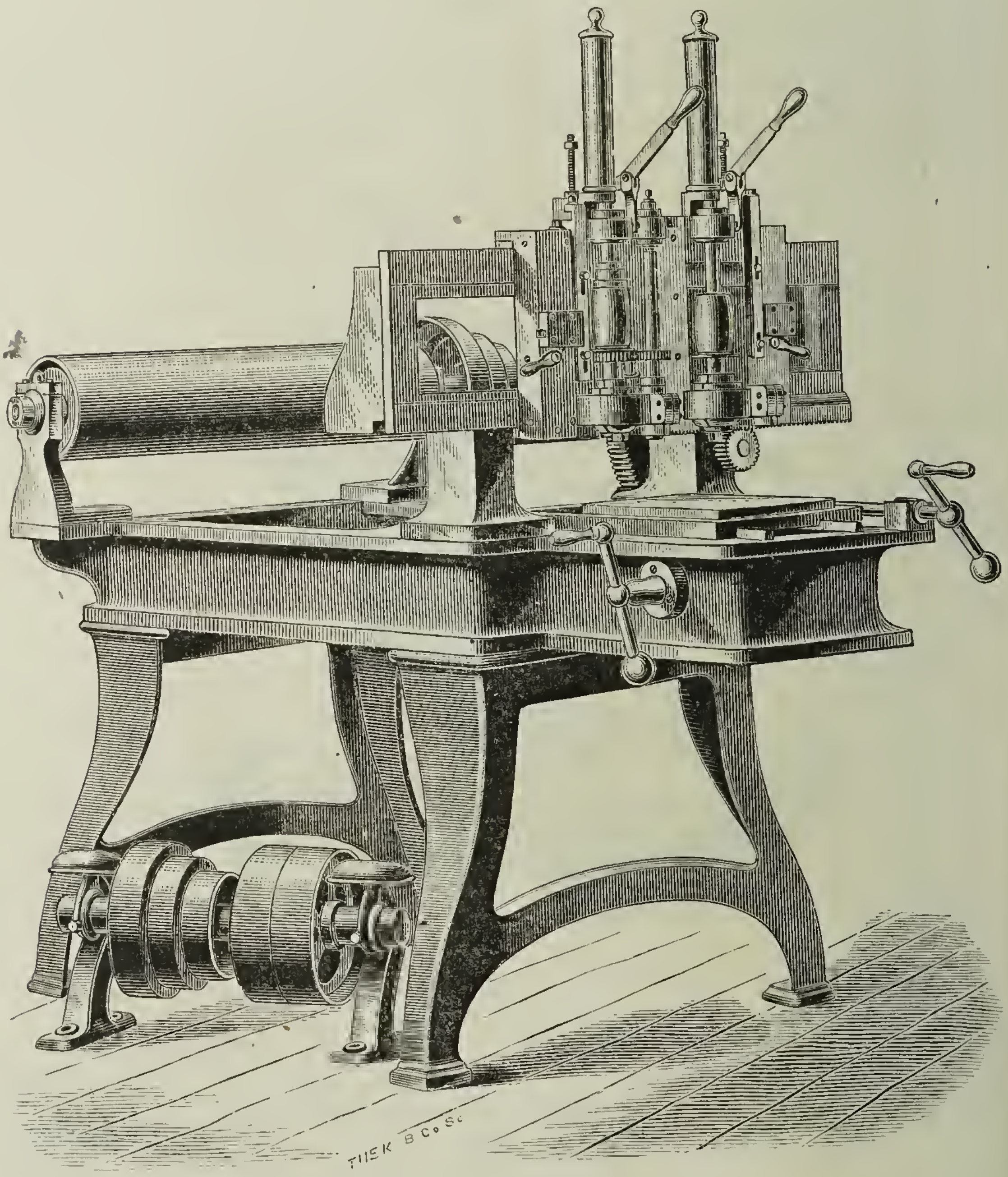


FIG. 103.—Two-spindle profiling-machine.

The gearing for moving the table and cross-slides is adjustable by means of double gears set, to prevent "back-lash," by two independent adjusting-screws, and also by a double rack adjusted in the same manner. This arrangement is indispensable to secure perfect accuracy in cutting irregular forms, especially in turning corners.

Two sizes are made. The engraving represents a No. 2, having an area of table of 15 by 12 inches.

Distance between top of table and under side of cross-head $4\frac{1}{2}$ inches, and between centers of guide-pin and cutter $4\frac{1}{8}$ inches. The cutter will profile or surface work to the extreme limit of the table-area.

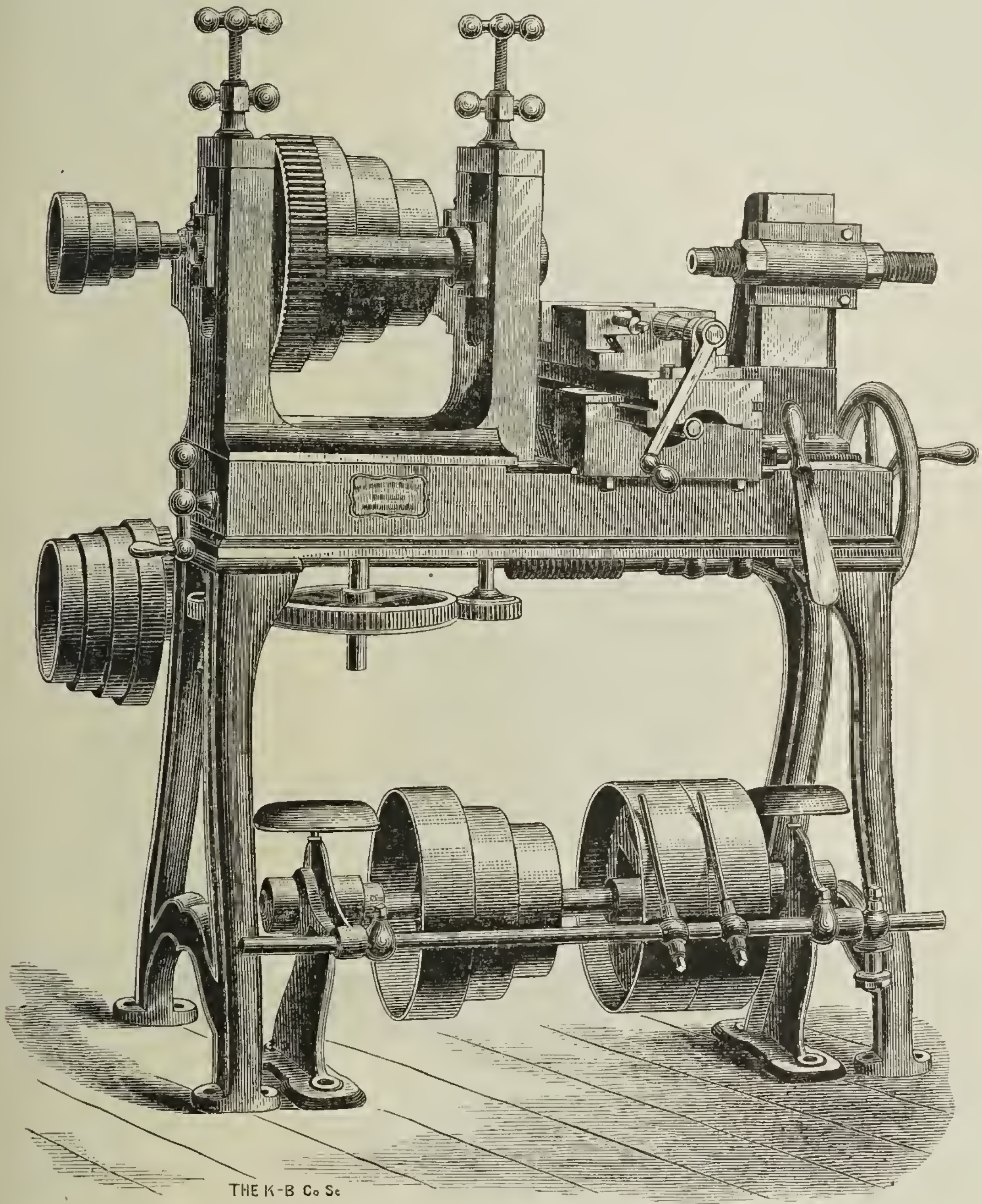


FIG. 104.—No. 2 milling-machine.

230. The No. 2 milling-machine (Fig. 104) is said to be in extensive use in armories and sewing-machine manufactories in this country and Europe and at the United States Armory, Springfield, Mass. It is also excellently well adapted to general work. It has self-acting screw-feed, with four changes of feed; self-acting stop-motion, adjustable at any point; a foot-stock for steadying the ends of long arbors in heavy cuts; a vise for holding work furnished with a permanent crank screw-wrench, and the spindle has a cone for three changes of speed, which may be varied by means of back-gears.

231. The four-spindle gang-drill (Fig. 105) is adapted to a variety of work where many pieces of uniform character are to be furnished, the

four spindles having each a separate tool for beginning and finishing holes. The table with the piece to be operated upon is raised either by hand or foot lever, by means of a rack and pinion, and a convenient gauge determines the depth of the hole to be drilled. The spindles are of steel, having two speeds, and the driving-cone has three grades.

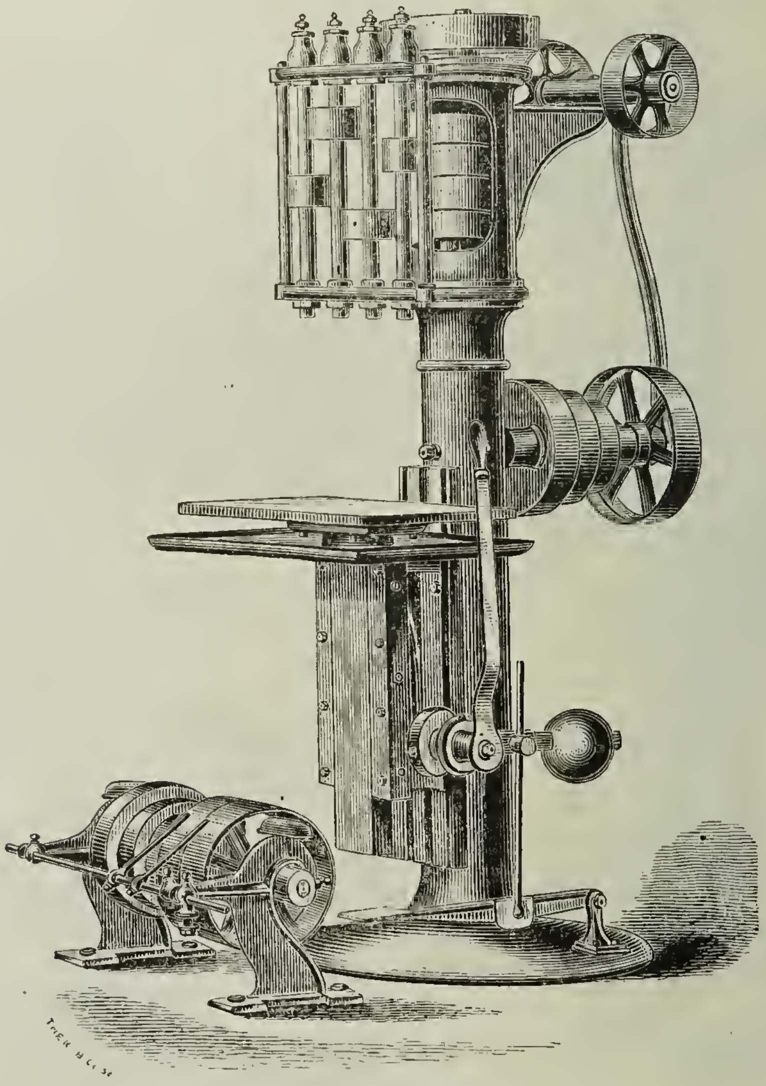


FIG. 105.—No. 2 four-spindle drill.

232. The No. 2 hand-milling machine (Fig. 106) is a convenient tool for general use. It is adapted to a variety of small work. The pieces to be operated upon are moved against the cutter by means of a lever, rack, and pinion. Cutters of $\frac{1}{4}$ to $2\frac{1}{2}$ inches diameter may be used. The head-spindle is of steel, and runs in boxes lined with "Babbitt metal." The table has a vertical adjustment of 15 inches, and the upper side a movement of $2\frac{1}{2}$ inches vertically, horizontal adjustment of 5 inches to or from the column, and a transverse movement of $5\frac{1}{4}$ inches. The machine is mounted on a column, the interior of which is a tool-closet.

233. The revolving head-screw machine, with wire-feed, (Fig. 107, is intended to form and finish screws of different sizes and lengths direct from the rod or wire without removing the material or interrupt-

ing the process. The revolving head is made to receive six distinct tools, including a gauging-stop to determine the length of the screw. Every operation of making a screw from the rod or wire is successively performed without removal of the work, change of tools, or stoppage of the machine. The Parkhurst wire-feed is operated while the machine is running by a simple movement of a lever, and has any range of length that may be desired. It is adapted to rods up to $\frac{7}{8}$-inch diameter. The different sizes of the machine are arranged for forming the thread by dies or cutting them with a screw-cutting tool. A cross-rest for carrying cutting-off tools may be attached.

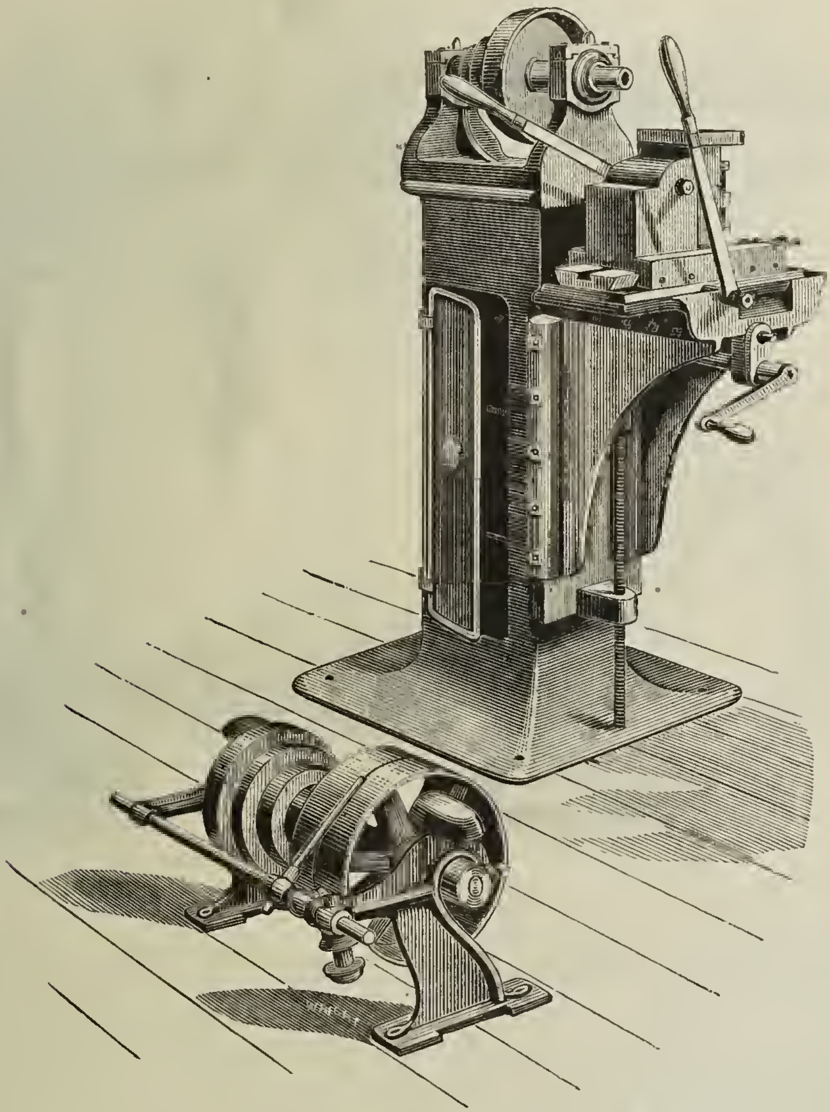


FIG. 106.—No. 2 hand-milling machine.

The engraving (Fig. 107) shows the No. 1 screw-machine, with the Parkhurst patent wire-feed attachment. The device does not seem likely to get out of order, and is a great assistance in facilitating work. It feeds and holds the wire in position without stopping the machine or delaying the work, as the operation of setting forward the wire and firmly clamping it is performed by a single movement of a lever. The turret is of steel, (as is that of the No. 0 machine,) is self-rotating and self-fastening, and the tools are held securely by convenient clamps. The cone has three grades, carrying a $1\frac{1}{2}$-inch belt. The counter-shaft is fitted with Pratt's patent friction-clutch pulleys. Case-hardened wrenches and an oil-tank were with the machine.

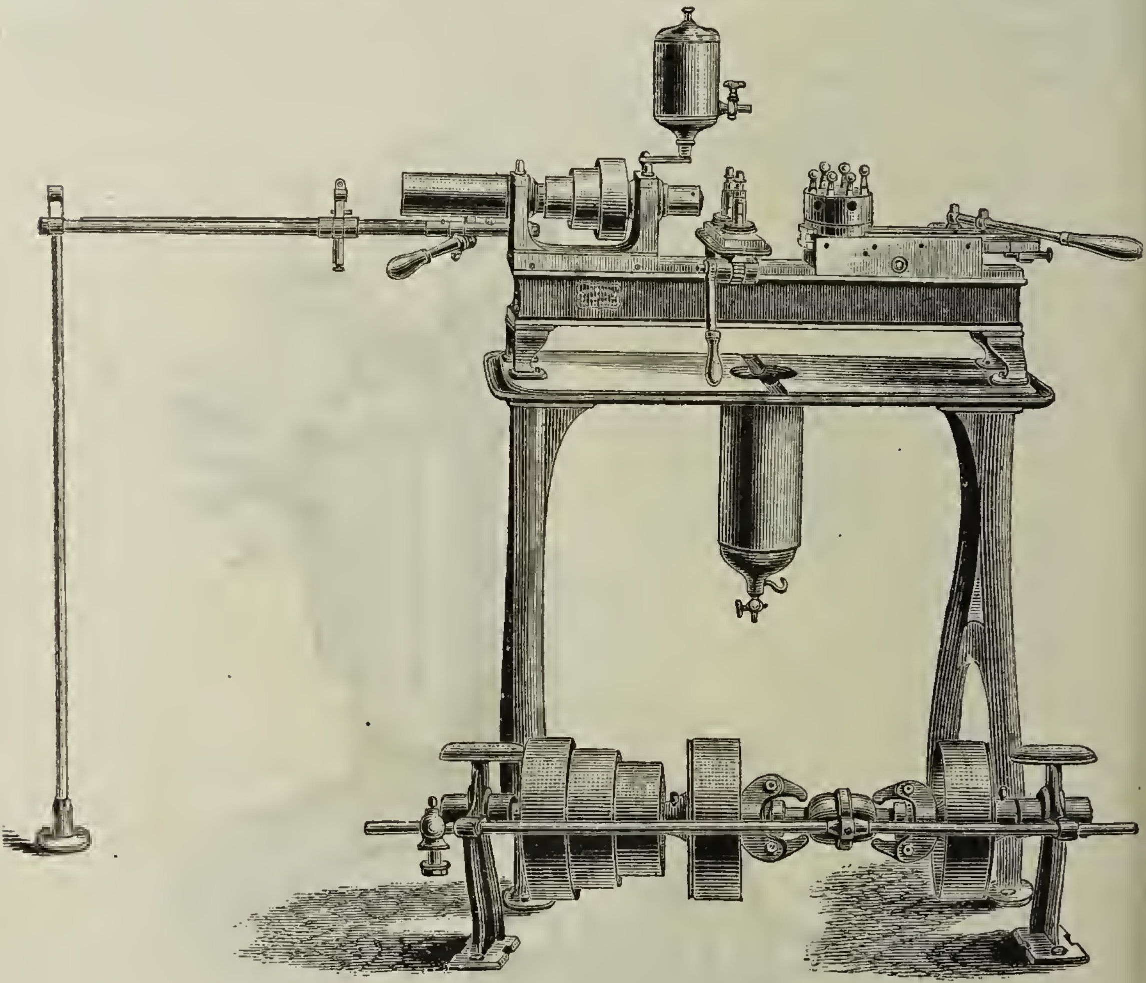


FIG. 107.—No. 1 revolving tool-head screwmachine, with wire-feed.

234. The 13-inch weighted plain engine-lathe (Fig. 108) swings 13 inches over the bed and 6 inches over the carriage. It has a pulley-feed, three changes from 60 to 160 per inch, a cone on the spindle for a 2-inch belt with four grades, large steel spindle, balanced cone turned inside and outside, and the boxes are lined with Babbitt metal, which is compressed after being run into the shell. All the parts are well fitted, insuring accuracy in turning, squaring-up, and boring. The foot-stock is secured in place by a cam-lever, the screws, nuts, and wrenches are case-hardened, and the counter-shaft is furnished with self-oiling boxes. There is a hole through the live spindle to receive rods up to $\frac{9}{16}$-inch diameter for convenience of cutting into lengths for studs, &c.

235. The cutter-grinder (Fig. 109) is a very convenient tool for shops and manufactories in which rotary cutters of any style are used for gear-cutting, milling, or slotting. A columnar support, with a broad base, sustains the spindle-head and the cutter-holder and guide. The

platen to which the holder and guide are attached may be adjusted in height to suit the diameter of the cutter to be operated upon. The guide rests against the tooth that is being ground, thus gauging the work perfectly, even though there may be irregularity in the size of the teeth. The machine is adapted to cutters of all sizes and styles of teeth, whether straight, beveled, or spiral. Either small grindstones or emery-wheels may be attached to the spindles.

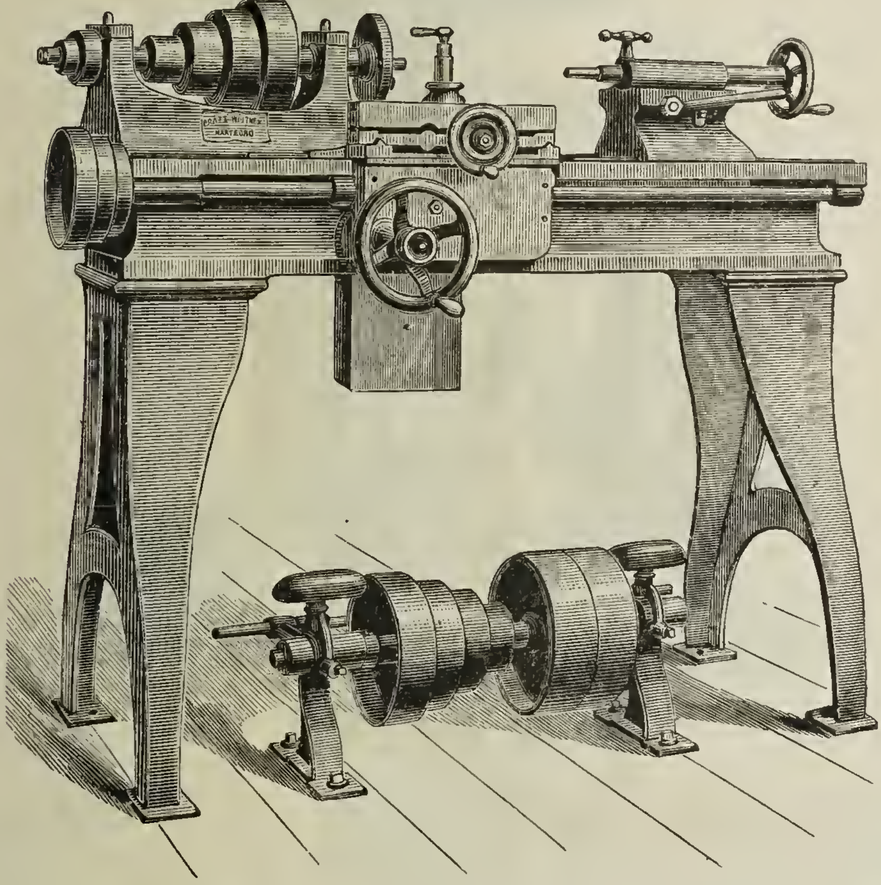


FIG. 108.—Thirteen-inch weighted-plain engine-lathe.

The weight, with counter-shaft, is 425 pounds; stated speed of counter-shaft, 480 revolutions per minute.

236. In operation the die-sinking machine (Fig. 110) is similar to the profiling-machine, the spindle being stationary, and the work to be operated upon being held in a vise, which may be moved in all directions horizontally by compound slides on the table of the machine, and may be elevated or depressed by the vertical movement of the platen or table. The cutter, which may be of any suitable size or form, revolves with the spindle, which is driven by a belt, giving much smoother action than is possible with gears. The work may be guided either by a pattern or forming-piece, or controlled wholly by the operator. This machine is very strongly built, insuring smooth work, freedom from chatter-marks, and is adapted to a great variety of work, being particularly efficient in forming and finishing recesses of either a circular, annular, or irregular shape, and for recessing dies for the drop-press. The differ-

ent movements of the vise and platen are independent each of the other, and are perfectly under the control of the operator.

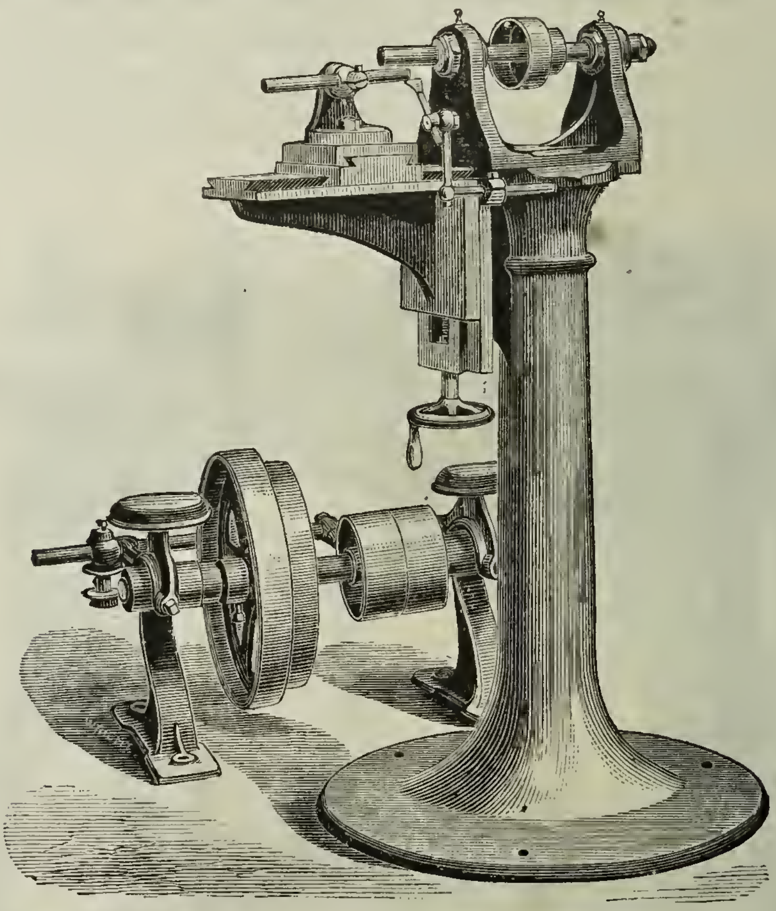


Fig. 109.—Cutter-grinder.

The greatest distance between the end of the spindle and top of the table is 24 inches. The platen has a vertical adjustment of 16 inches, and the horizontal movement of the vise is 10 inches. The counter-shaft has two sets of pulleys, giving two speeds, which may be varied on the spindle by a cone with three grades.

237. The tool represented in Fig. 111 is designed for a variety of work where the piece is to be finished by drilling, facing, and tapping holes without being removed from the chuck or face-plate. The revolving head carries from six to eight spindles for the reception of tools, and each one is brought to the work successively, by a single movement of a lever or handle, and is fed forward by a rack and pinion, operated by a convenient hand-wheel. The machine is rapid in its operation, and very accurate in its results. The number of spindles in the head may be varied to suit the work to be done, and the length of the bed may be increased or diminished, as ordered.

238. The size-designations of the planers indicate the width and height the machine will plane; thus, the 16-inch planer planes 16 inches in width and height, and in length 3 feet 2 inches. The length of the bed, as compared with the length of the table, is greater than is usual

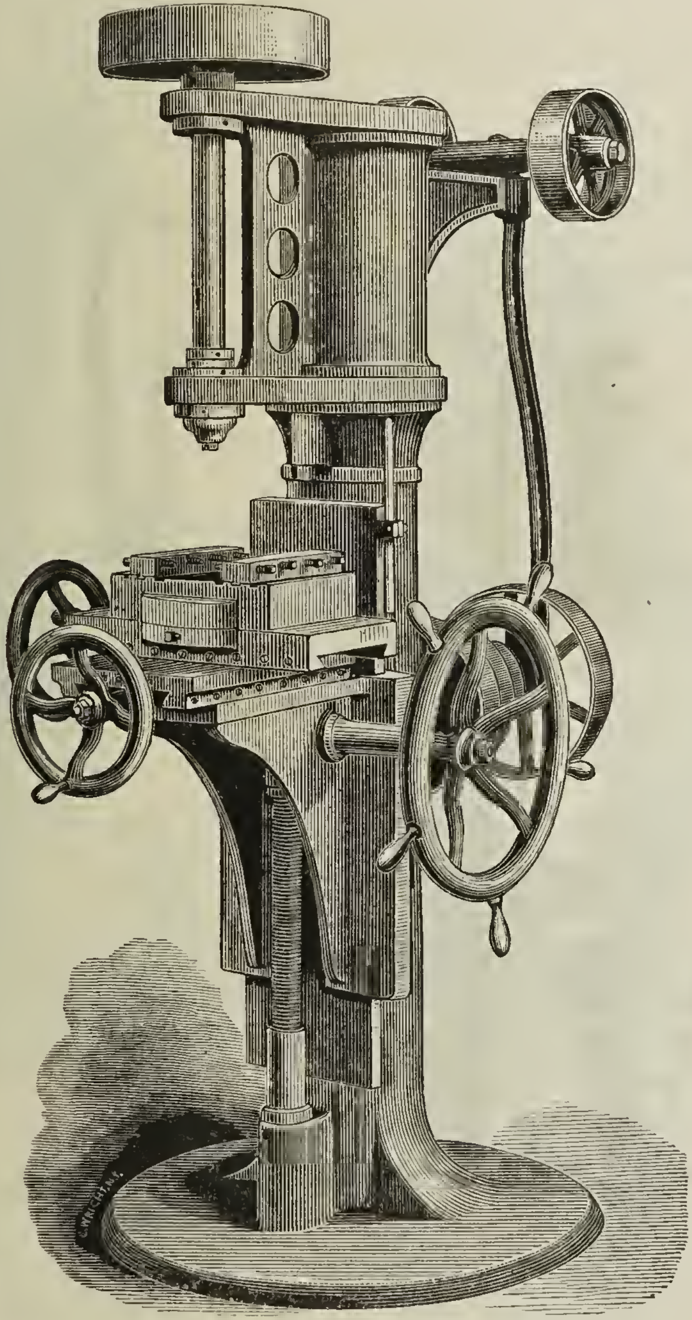


FIG. 110.—Die-sinking machine.

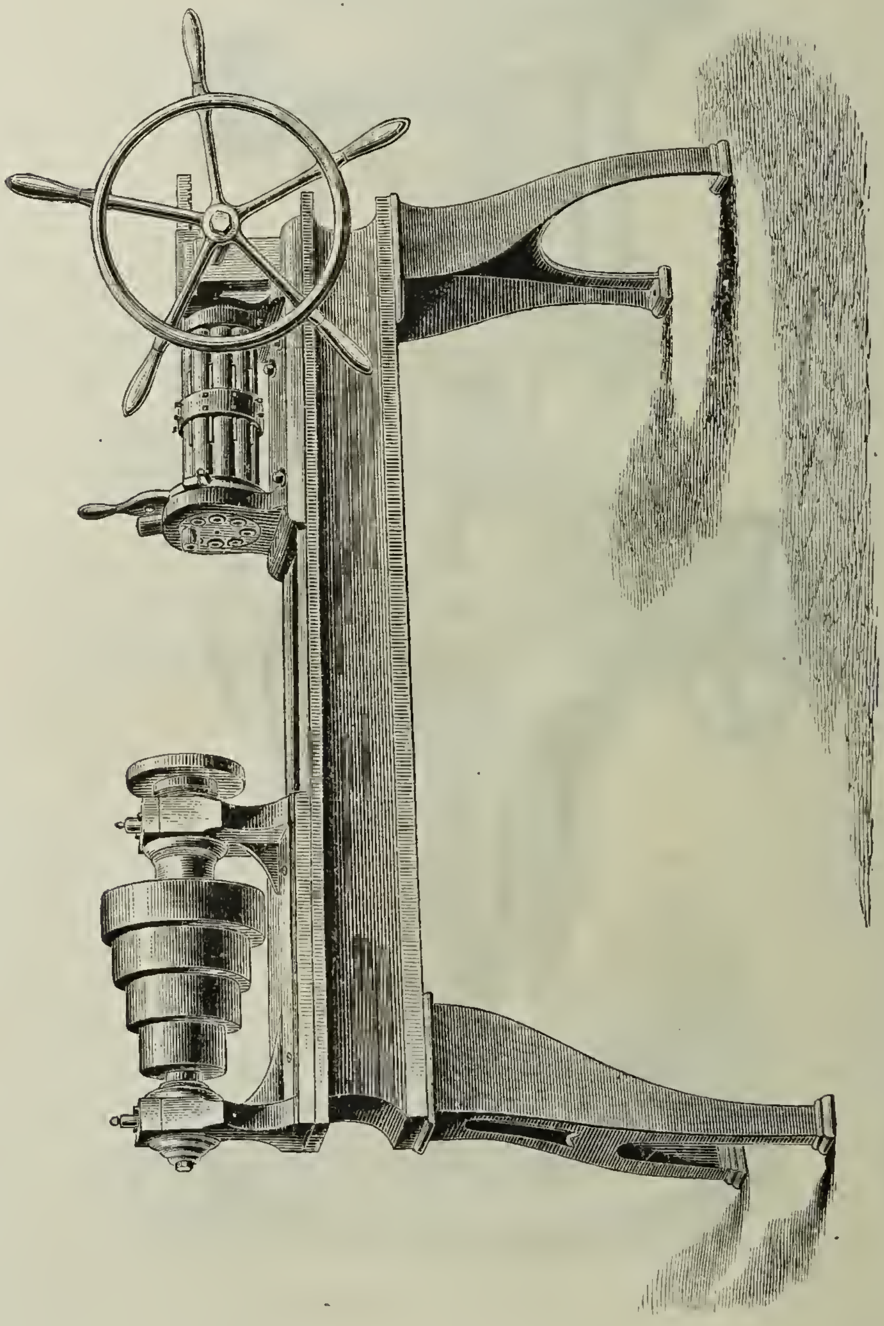


FIG. 111.—The horizontal revolving-head drilling or chucking machine, with eight spindles.

with this class of machines, preventing the tipping of the table from the bed when the rack is run out of gear with the pinion. The shafts are large, gears and racks accurately cut, sliding-surfaces perfectly fitted by scraping, and the nuts, screws, and wrenches case-hardened. This planer (Fig. 112) has automatic cross-feed, patent shipping movement, and movable dog, allowing the work, when desired, to be run either way from under the cutting-tool without changing the stops. Length of bed, 5 feet; length of table, 3 feet 6 inches; length that may be planed, 3 feet 2 inches; weight, with counter-shaft, 1,650 pounds; speed of counter-shaft per minute, 270 revolutions.

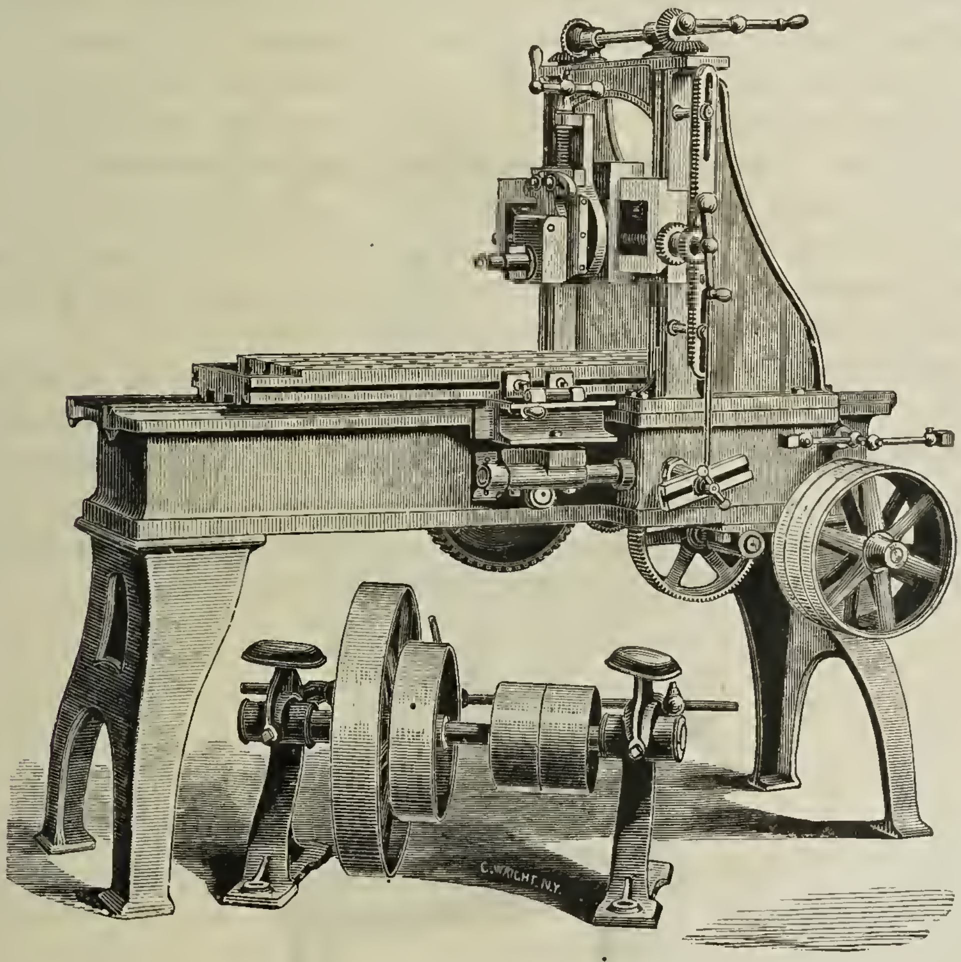


FIG. 112.—Sixteen-inch planer.

239. This firm seem to make a specialty of tools for such peculiar work as that demanded in sewing-machine and gun-making establishments. As has been seen, their tools are most creditable illustrations of this class—a class in which our manufacturers excel all others; and we were fortunate in being thus well represented.

The tools are illustrated with somewhat exceptional completeness, as excellent examples of these peculiar kinds of tools for rapid work on many pieces of usually the same, or nearly the same, form and size.

The modern system of *manufacturing*, as the term is used in contradistinction to simply *making* on single orders, has given occasion for the designing of an immense variety of these machines of special application. So great is this demand that many firms, like the Pratt & Whitney Company, are making their supply an important branch of business.

240. THE BROWNE & SHARPE MANUFACTURING COMPANY, of Providence, R. I., was another firm whose exhibits attracted great attention, and won for them unusual distinction. The milling-machines made by this firm were of the very highest order of merit. Their universal milling-machine obtained for them the highest honors at Paris in 1867, and has always been considered as among the finest tools made in the United States or in the world. This machine is, as the name indicates, intended to do an immense variety of work. It is capable of cutting at any angle, either horizontal or vertical, and is fitted up so as to make an excellent gear-cutter. The feeds are automatic, and capable of a wide range of variation in speed. There is probably no tool made which is so universally applicable in doing small work. The screw-machines of this firm are also of marked excellence in every respect, and do a wide range of work with invariable precision and in the most excellent manner. The cutters used on the milling-machines have a very excellent and valuable feature, which is peculiar also to them, that they may be ground, when dulled by use, without loss of form.

241. DESCRIPTION WITH ILLUSTRATION.—The following illustrated description of the exhibited tools of the Browne & Sharpe Manufacturing Company will indicate how well the preceding remarks apply to the design and proportions of these tools. Their finish was most excellent, and every part of every tool worked smoothly and accurately, with a uniform resistance which indicated thoroughly good fitting.

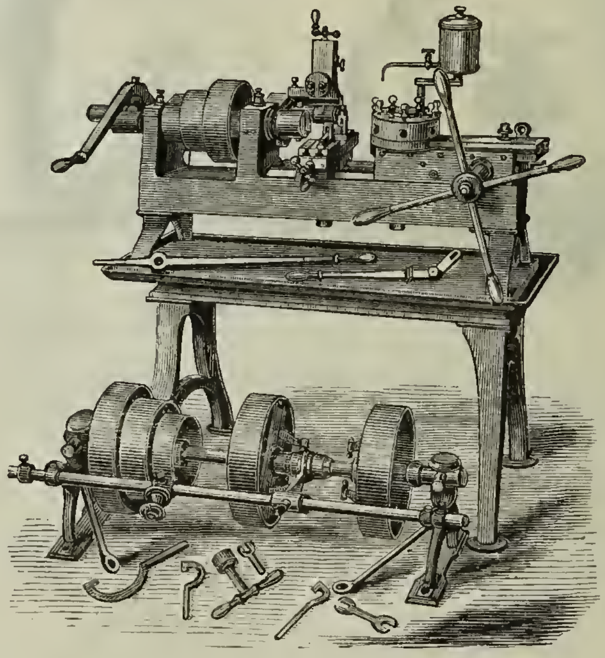


FIG. 113.—No. 1 screw-machine.

The No. 1 screw-machine, here shown in Fig. 113, is a small, compact, handy tool, and is suitable for making from bar-iron all kinds of screws and studs ordinarily used in a machine-shop. One man, with this machine, will, it is said, produce as many screws as from three to five men can make on as many engine-lathes, and they will be more uniform in size. Nuts can be drilled, tapped, and one side faced up, and many parts of sewing-machines, cotton-machinery, gas and steam fittings made on this machine, with a great saving of time and labor. The size of hole through the spindle is 1¼ inches. The size of holes in revolving head is $1\frac{1}{16}$ inches. The length that can be milled is 6 inches. The friction-pulleys on the counter-shaft, are 14 inches diameter and 3½ inches wide. Counter-shafts which run 170 turns per minute are furnished. The weight of the machine is about 1,450 pounds.

242. Their No. 4 screw-machine (Fig. 114) is of a somewhat different pattern, but it is also a very excellent tool. It is of the same general construction as the one previously described, but much lighter, and especially intended for making the smaller screws that are used by sewing-machine manufacturers, gunsmiths, and clock-makers. The spindle has a hole bored through it seven-sixteenths of an inch in diameter, and is provided with a patented device for opening and closing the jaws in the chuck which holds the wire from which the screws are made.

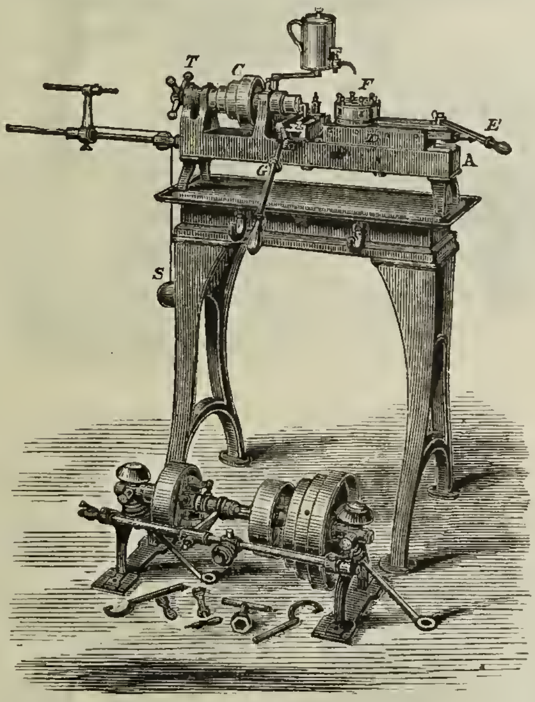


FIG. 114.—No. 4 screw-machine.

This operation of opening and closing the jaws of the chuck is performed in an instant without stopping the machine, and effects a great saving of time in making small screws. The revolving head is made entirely of steel.

The size of the hole through the spindle is $\frac{7}{16}$ inch; the size of the holes in the revolving head is $\frac{9}{16}$ inch; the length that can be milled is 2½ inches. Friction-pulleys on counter-shaft were supplied, of a neat and apparently effective pattern; they are 7½ inches diameter and 2½ inches wide on the face; the counter-shafts run 260 turns per minute.

Weight of machine prepared for shipment, about 450 pounds.

243. The "plain milling-machine" of the Browne & Sharpe Manufacturing Company, is exhibited in Fig. 115. It is a very strong, stiff, and evidently serviceable tool, and is excellently well fitted for a standard tool in the machine-shop to do plain work.

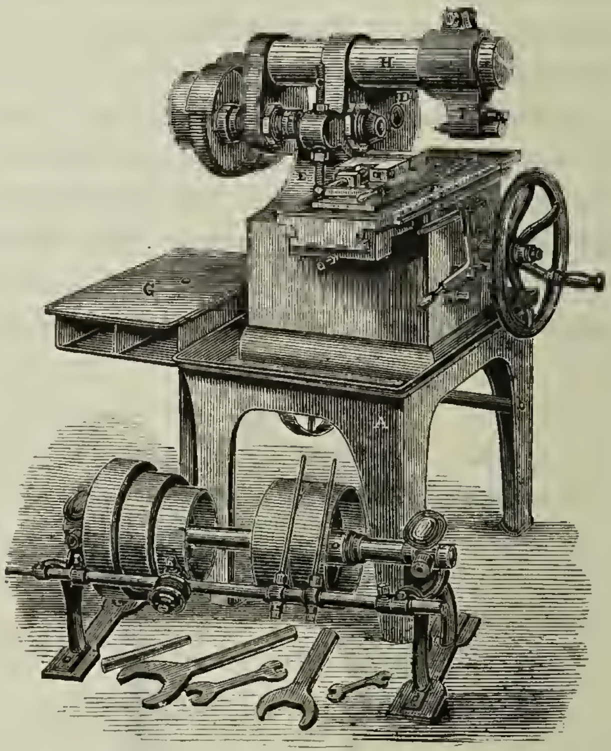


FIG. 115.—Plain milling-machine.

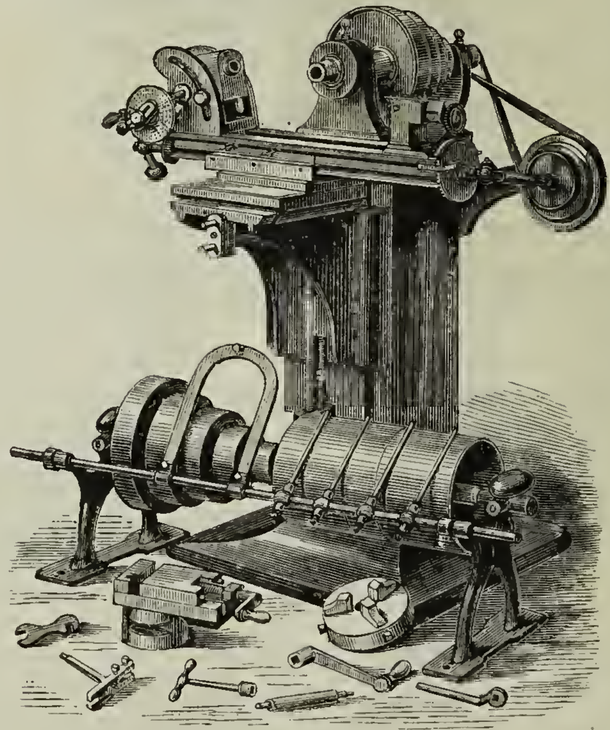


FIG. 116.—Universal milling-machine.

It is stated to be designed for ordinary milling-operations. The spindle is raised and lowered by set-nuts upon the screw C, and moved horizontally by nuts on the front box. The table is fed automatically, the feed being disconnected by the adjustable stop E. The spindle of the machine is provided with anti-friction bearings and arrangements to close up as wear takes place. Attached to the stand is a table, G, for holding work, tools, &c.

The whole length of the table is 28 inches, and whole width of table is 9½ inches; the distance of feed of table is 18 inches, and the height of center above table, at the lowest point, is 2⅝ inches; the height of center above table, at the highest point, is 6 inches; the vise-jaws are 5 inches long and 1 inch deep.

244. The most beautiful machine in this collection, however, was the "universal-milling-machine," the same tool which attracted so much attention and secured so high an award at Paris in 1867. (Fig. 116.)

The machine has all the movements of a plain milling-machine, and the following in addition: The carriage moves and is fed automatically, not only at right angles to the spindle, but at any angle, and can be stopped at any required point. On the carriage, centers are arranged in which reamers, drills, and mills can be cut either straight or spiral. Spur and beveled gears can also be conveniently cut. The head which holds one center can be raised to any angle, and conical blanks placed on an arbor in it cut straight or spirally. Either right or left hand spirals can be cut. The pulleys on counter-shaft are 14 inches in diameter, and the whole width of the three 15 inches. The counter-shaft runs 110 turns per minute. The weight of the machine, with overhead work, prepared for shipment, is about 1,500 pounds.

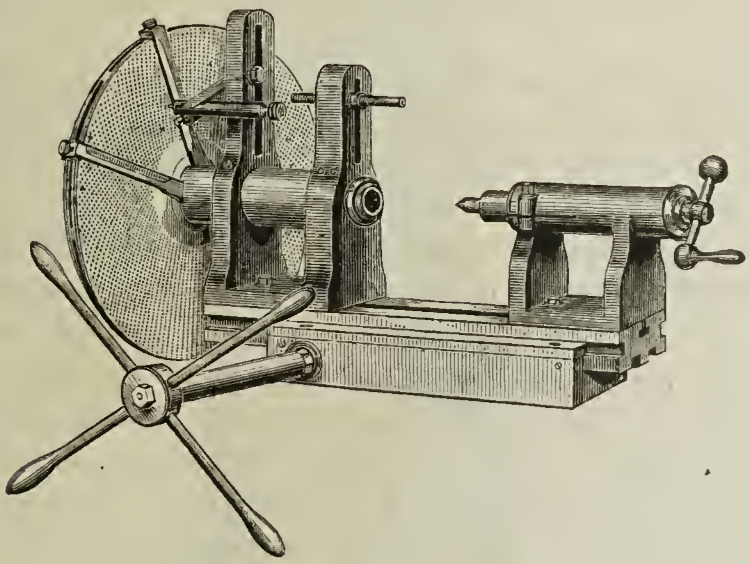


FIG. 117.—Gear-cutting attachment to the universal milling-machine.

The machine, with the attachments just exhibited and enumerated, is capable of doing an immense variety of work which cannot be done conveniently or well by the ordinary standard machines. Its extremely accurate workmanship and its convenience of adjustment and operation make it a most valuable addition to the usual machine-shop plant.

The writer has had ample opportunity to study this machine, as fitted up in the workshop of the Mechanical Laboratory of the Department of Engineering of the Stevens Institute of Technology, and has been unusually pleased with its beautiful workmanship; its remarkable range of application and the excellence of work done by it.

The machine is also furnished with a gear-cutting attachment, (Fig. 117.) This is designed to accelerate the operation of cutting gear-wheels and for cutting larger and heavier wheels than can be cut with the ordinary apparatus belonging to the universal-milling-machine. It swings 13 inches, and is furnished with a 20-inch index containing 4,294 holes. It will divide all numbers to 75 and all even numbers to 150. Arbors fitted to the universal-milling-machine can be used in this attachment. The screw with set-nuts over the spindle is designed as a support for the wheel while being cut.

The collections of the three firms above described were unrivalled in the whole Exhibition, and were commended, by all who saw them, as equally admirable in design, material, and workmanship.

245. Messrs. STILES & PARKER, of Middletown, Conn., exhibited a collection of tools for various uses. The most interesting were their presses.

The Hotchkiss and Stiles drop-press (Fig. 118) is of that class in which the hammer is raised by a stiff belt or a board passing up between two friction-rolls. The improvements of this drop are those of Mr. Bennett Hotchkiss; the firm claim the following:

1st. Such an arrangement of parts that it makes a very excellent jobbing-hammer. They expect it to take the place, to a great extent, of all other kinds for forging. In addition to the upright rod, which is operated by the hammer to open and close the rolls, they have placed another rod, the lower end of which is secured to the end of a lever, which is operated by the hand or foot, which operation also opens and closes the rolls at will. The lower end of this rod has a slot, so that the action of the hammer will not disturb the hand-lever, thereby preventing the hand being injured, as otherwise would be the case.

2d. No dog is used on the upright to hold up the hammer. The belt or board passes up between two clamps, situated under the rolls, so arranged that as the hammer ascends they will freely open themselves, but on descending they will close and hold up the hammer. To let the hammer fall, the clamps are opened by pressing upon the foot-treadle.

3d. The board or belt is secured to the hammer by an elastic connection, which prevents the sudden jar, and its consequent destruction. The back is made adjustable to different thickness of board or belt, as also are the clamps. An adjustable collar on the upright rod allows the operator to obtain any height of blow desired automatically. If one blow

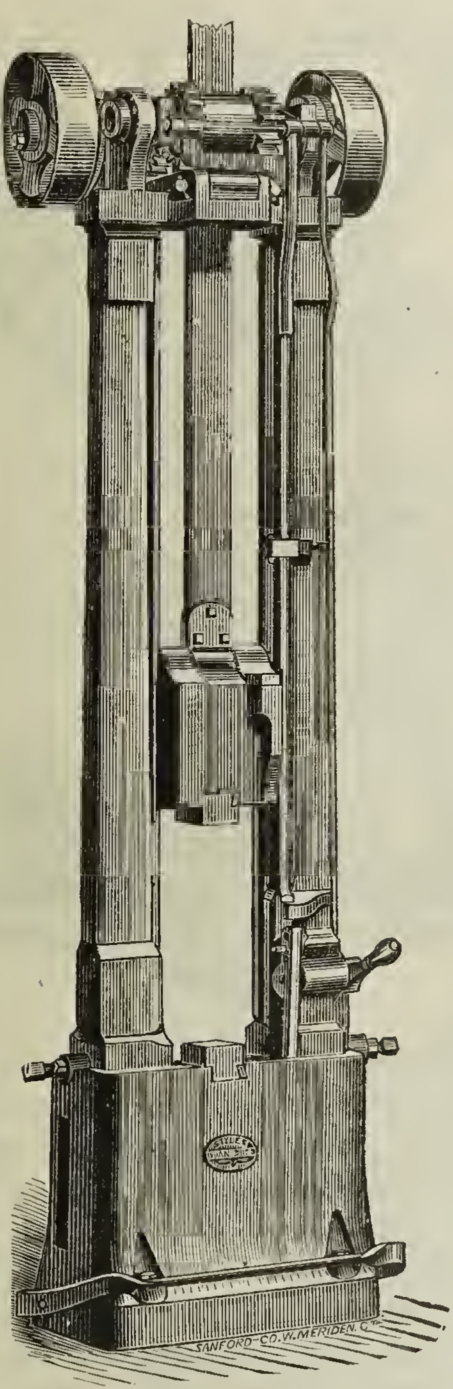


FIG. 118.—The Hotchkiss or friction-roller drop, with Stiles' improvements.

is wanted, he first presses upon the treadle, then removes the pressure as soon as the blow is given. Keeping the foot upon the treadle, the blows are repeated until the foot is removed. If a blow of less height than the collar is set for is required, the hand-lever is used, giving any height of blow desired. The hammer can be held up at any point below the collar by bringing the hand-lever into action when the hammer is at the desired height, so that the next blow can be given from a state of rest of less height than the collar is set for. This is a feature, it is said, which no other drop has; thus the first blow struck can be of less height than the second or third, and obtained from a state of rest. A gentle pressure of the foot upon the treadle will allow the hammer to go down slowly, but it will stop and remain suspended at any point as soon as the pressure is removed.

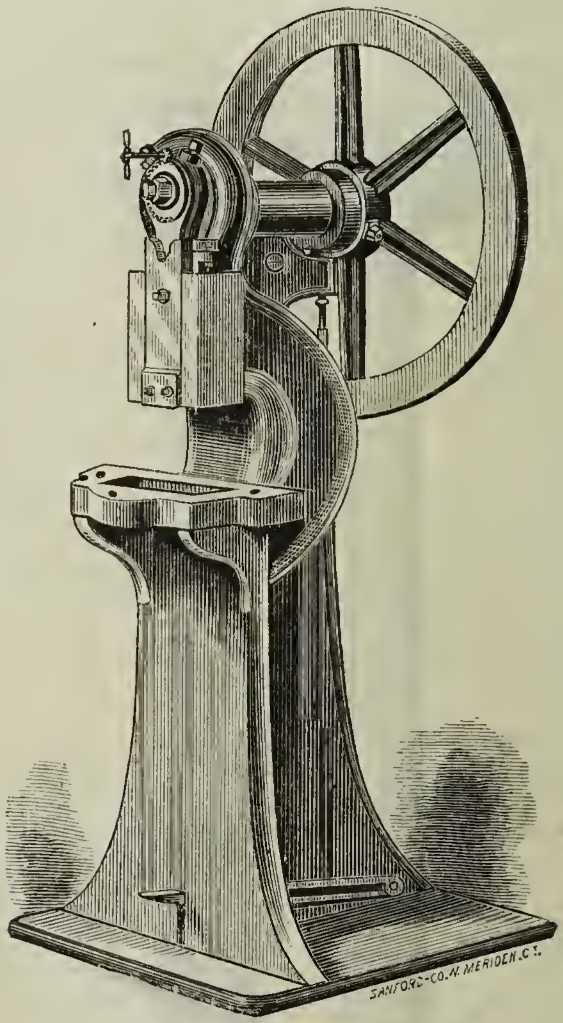


Fig. 119.—The Stiles power-punching press.

The clamps holding up the hammer keep the board from touching either roll, and this prevents them from being worn unevenly.

246. Fig. 119 represents the Stiles power-punching press, as exhibited by the same firm, and Fig. 120 illustrates the construction of a much more powerful tool of the same kind. These tools are neat and

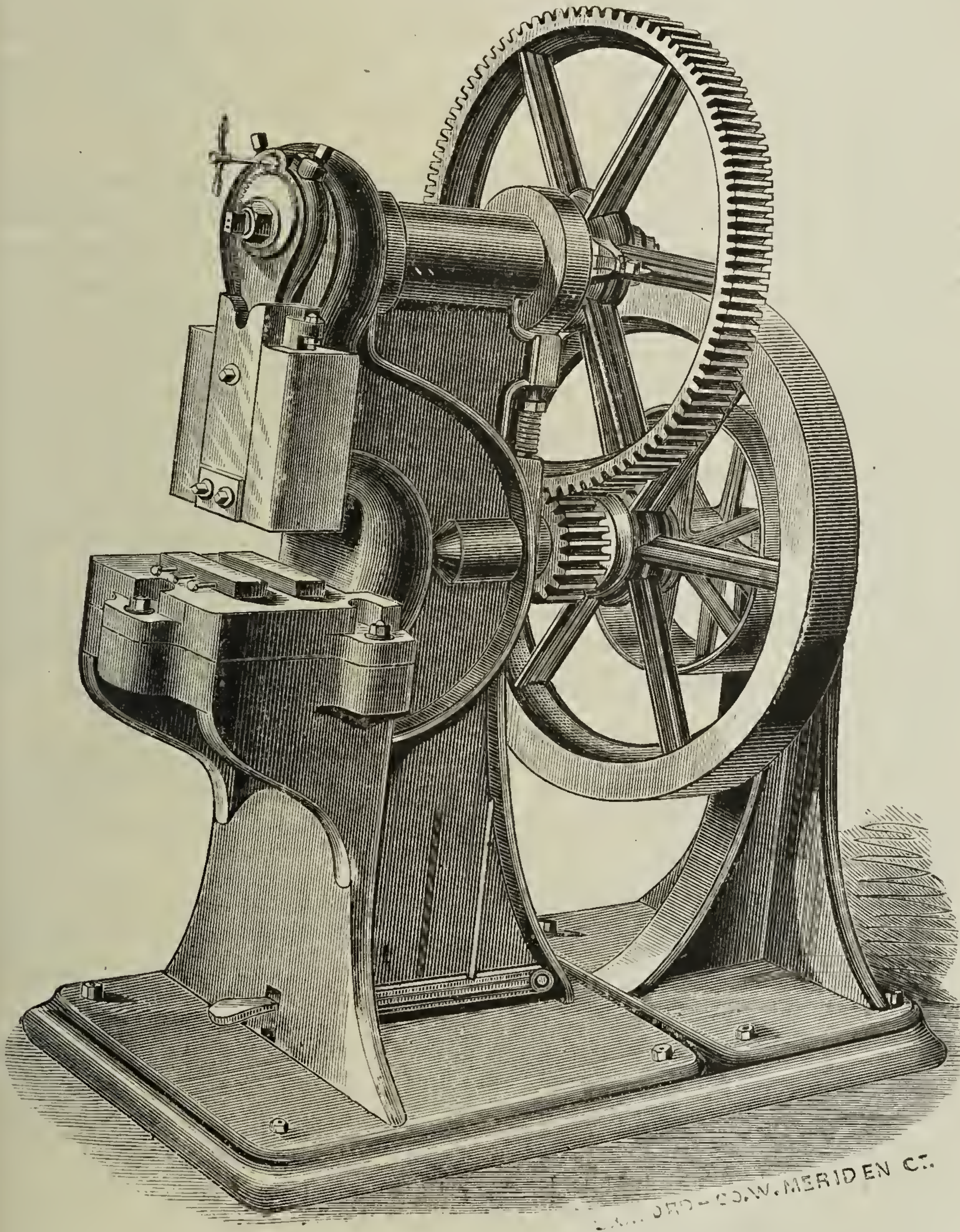

ORD - CO.W. MERIDEN CT.

FIG. 120.—The Stiles power-punching press.

substantial in design, well built, and possess some decided advantages over older forms of press.

It is important that the press should be so arranged that it may be stopped after a single revolution and at the top of its stroke, in order that the work may not be spoiled by the return of the die before the workman brings it into the right position for the succeeding action of the punch, and in order that there may be the greatest possible amount of room for the adjustment of the piece. Many ways of accomplishing this result have been tried. In these presses the device is very simple and perfectly effective.

The upper end of the pitman or driving-rod carrying the slide is bored out sufficiently to receive an eccentric which fits the crank-shaft snugly, but which may still slide freely. This eccentric is turned by a small pinion on the head of the pitman, which pinion is turned by a handle projecting at the side. Turning the eccentric, the punch is raised or lowered, still remaining in rigid connection with the driving-shaft. The length of stroke is not varied, but the limits of throw are altered by the full range of the eccentric. When it is turned down the punch rises clear of the metal to be punched, then descends through it and into the die. When turned up, the punch still rises and falls, but never descends so far as to strike the plate or the piece of metal which the workman is adjusting upon the die. These parts are of steel, with bronze (gun-metal) bushings on the crank-pin and shaft, which may be replaced whenever worn. This gives great accuracy of action without throwing the bearings out of line or bringing any extraordinary strain upon the machine.

The automatic stop applied to these machines is an excellent improvement. The punch may not only be stopped at the highest point, but also with the punch close to the sheet when the workman wishes to secure unusual accuracy of adjustment.

The manufacturers stated that they have built eight thousand of these presses on orders in the United States, and had filled orders for government and private shops in nearly all European countries, the Prussian government having taken fifty machines.

247. BRITISH CRITICISMS OF AMERICAN DESIGNS.—The distinguished British authority already quoted concludes a survey of the American tools, of which the description has just been given in greater detail, by remarks which are of the most complimentary character, and, made as they are by a writer who has no interest in doing more than simple justice to our countrymen, and who would naturally be expected to be influenced, if in either direction, by a natural prejudice in favor of British tools and tool-builders, are likely to prove most gratifying to every citizen of the United States.

The friendly criticism, at the same time made, is well founded, and will be received in the same fair spirit in which it is given.

London Engineering remarks that the American metal-working tools "are of special interest, and that they are decidedly characterized by great originality of design. In this respect they are, in fact, distinguished beyond any other collection of machine-tools at Vienna, each tool shown in the American section being a specialty of its makers, and embodying a greater or less number of ingenious devices, which distinguish it from the production of other firms. The workmanship, too, of the various machines shown is excellent, and every care appears to have been taken to insure accuracy. The only fault, in fact, which we have to find with the American machine-tools is that some of the frames are not what they should be. With a few exceptions—and notably Messrs. Sellers, whose frames are excellent—our American friends are apt to run a little wild in the matter of frames, and we miss in their designs the solidity and simplicity which distinguish the productions of our leading English firms. Hollow or cored frames are not so largely used in the United States as they are now with us, and the ribbed frames which are adopted, although probably amply strong enough for their work, are apt to be distinguished by many unnecessary curves and twists, which certainly do not add to their rigidity, and which we cannot regard as lines of beauty. This is especially noticeable with the legs for supporting the smaller machines. In the design of machine-framing there is, however, we believe, a steady improvement taking place among American makers, and we expect that in a few years the productions of all the leading firms will be as good in this respect as they undoubtedly now are in other and perhaps more important details."

The same periodical, in commenting upon the exhibit of machinery in the United States section of the Paris Exhibition of 1867, remarks of the machines of Sellers & Co.: "In the designs it would be difficult to point out any precise English original; there is nothing but the mode of distributing the material, and the manner in which most of the details are constructed, which shows Mr. Sellers's really intimate acquaintance with English practice. In every other respect there is a decided originality about these machines, placing them upon a totally different level from mere imitations, and giving in many instances to Mr. Sellers the credit of having originated some of the most useful specialties of tools now to be found in English workshops."

248. What is here said of Sellers & Co. is also true of nearly all American manufacturers who sent their goods to Vienna. American ingenuity and the American system of manufacturing in large numbers and with exchangeable parts, and the use of special tools, are well recognized throughout Europe, and are noted by all engineering papers. Builders of machinery from all countries, and professional engineers of every class, stated that the United States section was to them, small as was the collection, a mine of wealth in its combined originality and excellence of both design and construction. The only real competition is between American and British builders, and here it is extremely close, as it should be expected to be between what are really divisions of the

same nation. Could we combine more thoroughly British solidity and thoroughness of work with the distinctive excellencies of the work of our people, we should never find dangerous rivals. The Germans are not unlikely, however, to develop ultimately such a combination of characteristics, and we may well congratulate ourselves as a nation that so large a proportion of our foreign population is coming from Northern Euope.

The criticism of American machine-tools given above was taken from a British journal as, in the main, very just, and as coming from an unprejudiced foreign authority of well-recognized standing. The following are remarks made by the same authority upon the British exhibits:

"Leaving the American collection, and passing on to the British section we cannot but be struck by the difference in the character of the exhibits. In the American department almost every tool possesses some novel feature, and each is distinguished by an individuality which shows it to be the special design of its maker; while in the British section the great majority of the tools are reproductions of old and well-known patterns, possessing scarcely any interest whatever as exhibits. Messrs. Sharpe, Stewart & Co., of Manchester, show, it is true, a collection of tools which, as far as good design and workmanship are concerned, are all that could be wished for; but we could have wished that the exhibits of this firm had been accompanied by others from our other leading makers."

249. THE BRITISH METAL-WORKING TOOLS were usually well designed and splendidly constructed, of the best material.

The firm of SHARPE, STEWART & CO. were not as fully represented as a subsequent visit to their establishment indicated that they should have been. In their exhibit was a Sellers planing-machine, of which the Messrs. Sellers themselves need not have been ashamed, but with some slight modifications of design, which were, perhaps, of doubtful value. Their slotting-machines were fine tools, but demand no detailed description. Their shaping-machines and their drilling-machines were of the best proportion and the finest workmanship.

The WEBB WHEEL-FINISHING MACHINE, for trimming out the insides of the rims of railway-wheels, was one of the best tools here. The forged wheel is a somewhat awkward piece to finish up.

The machine was designed by Mr. Webb, of the London and Northwestern Railway Company, and is of some value as assisting in an important degree by trimming out the inside of the wheel rim between the spokes. It is shown in the accompanying sketch, Fig. 121. It consists of a strong bed, like a lathe-bed, on which is mounted a horizontal face-plate which may be rotated by means of a worm acting upon a screw cut upon its periphery. On this face-plate the wheel is carefully set so that its center may coincide with that of the plate, and it is then clamped firmly in place. At the extreme end of the bed-piece is mounted a train of gearing driving a disk which carries a pin. This pin engages the arm of a lever, giving it a slow rise and quick return-stroke. On the opposite side of the fulcrum is an arm carrying the tool-holder, which is thus made to vibrate in an arc of proper radius to shape the interior of the wheel-rim, giving the desired convexity. The position of the face-plate is determined by the size of wheel to be planed up, and is adjusted by a screw traversing the bed, like the feed-screw of a lathe, and moved by a handle at the end.

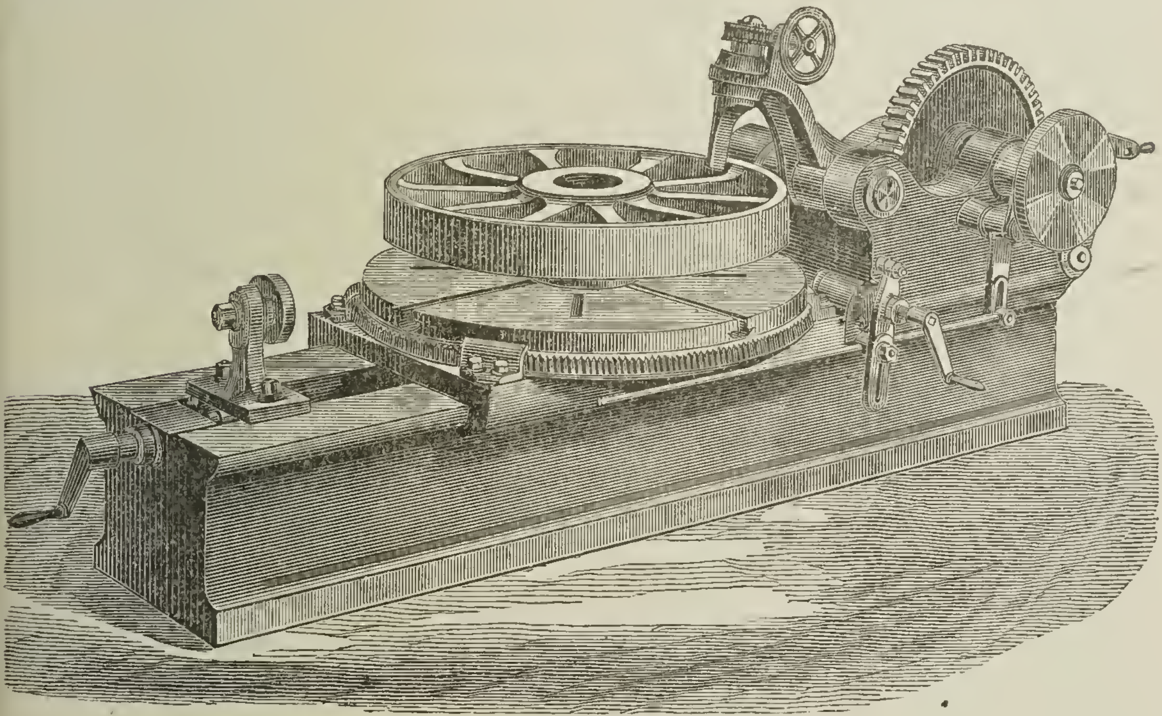


FIG. 121.—Webb's wheel-finishing machine.

250. Messrs. C. DE BERGUE & CO. displayed one of the finest collections of machine-tools in the machinery-hall. They were best represented by their boiler-makers' tools, of which they seem to make a specialty.

Their punching-machines were heavy tools, and drove their punches through the heavy iron plates without the slightest springing and without the slightest check in their movement. The shears were equally strong and well made. The most interesting tool was the rivet-making machine. It was, however, less perfect than those which our own mechanics are familiar with, and deserves mention principally because of its substantial design and its excellence of material and workmanship.

Messrs. HIND & CO. exhibited some plain, strong, well-built tools, which were evidently intended for hard service, and, although well made, were by no means extravagantly finished. They exhibited no noticeable novelties in design, and there seemed to be no points in their practice which might serve as models to our own builders.

Messrs. NEW & CO. exhibited a good collection of tools of common forms and of plain finish. The work on them was fairly done, and the tools were such as would find a good market among dealers in low-priced machinery. Their railroad-axle and wheel-turning lathes were excellent tools.

The British exhibit of machine-tools was not what it had been hoped and expected that it might be. The reason given for the non-appearance of many well-known firms and for the small collection of tools exhibited by those who did present themselves was the fact that tool-builders had been extremely busy for many months preceding the opening of the Exhibition, and had been unable, frequently, to fill regular orders. It is greatly to be regretted that so few of the most celebrated English and Scotch makers were represented, and that out of a vast number of new and important improvements which have lately been made by them, but a very small fraction should have been exhibited.

251. The "Artisan" reporter to the British "Society for the Promotion of Scientific Industry" remarks, in his report to that society on machine-tools: "I may say that I was very much disappointed with the exhibits from our own country."

* * * * * * *

"Comparing the whole of the English exhibits with those of Germany and Austria, we are entirely put in the shade. I am glad to say that this country was very badly represented, and must not be judged by her exhibits at Vienna, or else, in place of standing A 1, she will sink below Germany, Austria, and America."

A careful inspection and comparison of all exhibits in this class would, however, indicate that the last-quoted writer was somewhat too severe in his judgment of his own people.

252. FRENCH, BELGIAN, AND SWISS METAL-WORKING TOOLS.—In other sections there was comparatively little which requires description.

The French tools possessed neither the substantial character of the British nor the peculiarly ingenious adaptation to their work noticed in American tools, but many of them were of good design and elegant form, and were very well finished. In the French section, there was an extraordinarily large display of machinery for the manufacture of chocolate, and of soda-water, and of soaps, some of which were remarkably ingenious and very efficient.

Messrs. DANDOY-MAILLARD & CIE, makers of light machine-tools, exhibited some very good machinery, and some of the tools very ingeniously adapted to special purposes.

L. DENY exhibited a collection of presses and mint-machinery of excellent design and construction. The finish was the best seen in this section. Their coining-press was driven by friction-wheels arranged to reverse promptly, and they worked admirably. The products of these presses were coins and various kinds of peculiarly-shaped pieces, such as are more frequently made in the United States by means of the drop-press, and also what are sometimes designated as "Birmingham wares." In many cases, they were beautifully executed. Each member of the jury was presented with samples of this work and of medals struck off in their presence.

MM. LAMBERT & CIE exhibited nail-making machinery, which was well made and did good work. As the best work of this kind is probably done in the United States, it is unnecessary to describe this exhibit.

MM. BARIQUAND & FILS exhibited the finest collection of "*fraises*"—rotary cutters for milling-machines—that the writer has ever seen. They were equally remarkable for their variety of form, excellence of workmanship, and cheapness. The exhibitors state that they represented, in material, workmanship, and finish, their standard marketable products, and that equally excellent cutters were invariably furnished at the prices given in the catalogues furnished to the jury.

Belgian tools were, in character, intermediate between those of France and of Great Britain. They were usually of excellent character.

The principal exhibitor was the firm of BEDE & Co., of Verviers, who also exhibited a large collection of textile machinery. There were, however, no new designs.

An Alsacian firm, the proprietors of the Ateliers Ducommun, exhibited some of the best tools in the Exhibition. Some of them were of original design, and all were of excellent material and fine workmanship. Among their tools was a copy of an American screw-cutting machine, which was an acknowledged fac-simile; but as it was a fac-simile in excellence of construction as well as in design, its presence was a compliment to the original manufacturers with which they may justly feel pleased.

253. RIETER & Co., of Winterthur, Switzerland, exhibited most creditable work, and of designs which were in some cases novel; in other instances, they were very nearly fac-similes of tools well known in the United States. This Swiss work was generally excellent. The most noticeable machine was a large and heavy drilling-machine, in which the drill-spindle was mounted on a traversing-head, somewhat resembling that of a planer, which head was made capable of sliding laterally, with a reciprocating movement, for the purpose of working out slots. This traversing motion was given by a revolving disk, recessed into the main cross-head, or girder, which disk carried a pin connected by a rod to the drill-holder. The motion of the disk was obtained by a very neatly-arranged train of mechanism, which attracted much attention from the jury.

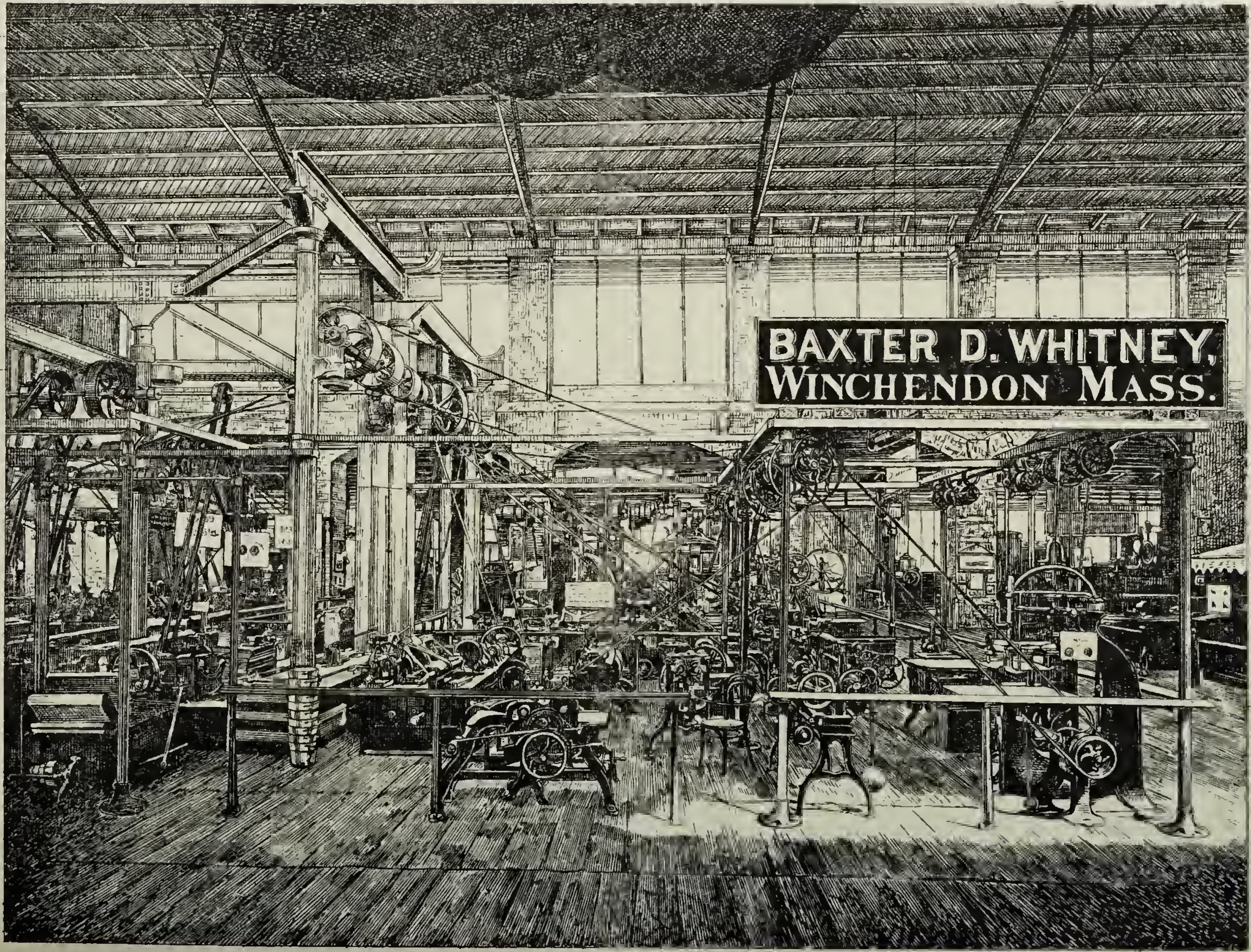
254. OTHER EUROPEAN TOOLS.—The firm of Pfaff, Fernau & Co., of Vienna, exhibited a considerable collection of tools of good design, and of unusually excellent workmanship.

Zimmermann, of Chemnitz, Saxony, and his rivals, Schmalz and Hartmann, presented collections of tools, of which the designs were evidently British and American. They were of good material, and usually of most creditable finish.

Bede & Co., of Verviers, Belgium, exhibited the best work from that country. Belgian work stands only second to the British and American.

The Swedish section contained some very good tools, of designs which were in several instances of American origin. They deserved more consideration than they received. They were usually of designs familiar to American mechanics, and chosen with an intelligence that indicated an appreciation of their best points. The material was apparently excellent, as might be expected of the country which has the reputation of producing the finest iron in the world. The workmanship was good, and the finish was appropriate, sensible, and satisfactory.

Vienna Exhibition 1873. Machinery etc.



American Photo-Lithographic Co N.Y. (Osborne's Process)

WOOD-WORKING MACHINERY.

255. The same characteristics which are observed in the study of the metal-working tools of the several nations are also seen in even a more marked degree in the wood-working machinery.

Here, also, the sharpest competition was between the builders of the United States and those of Great Britain. The several principal types of wood-working machinery are probably of British origin. American mechanics have, however, originated a vast number of machines for special purposes, and have so improved many machines which have been long known that they are almost to be regarded as new tools.

British and other European builders have copied extensively from our own makers of tools, and have frequently modified the designs. In such cases, British makers have sometimes improved the machines by strengthening and stiffening them, enabling them to do more and heavier work, while adding somewhat to their cost. Continental builders have rarely improved these tools while copying them; and having copied them in some cases with modifications, they have exhibited an unhappy facility of detracting from their efficiency where it was intended to improve them.

256. GENERAL CHARACTERISTICS.—The first notable distinction, this difference in the weight and solidity of British and American tools, strikes the eye of the mechanic at once. The former are also invariably painted with plain colors, while the latter are sometimes most elaborately adorned with a variety of colors, which offend the eye by their intensity, their inappropriateness, and their inharmonious arrangement. The forms of the tools from the United States, and their general design, indicated, by their variety and their special characteristics, the wonderful variety of wood-working to which they must be adapted to meet the demands of purchasers in this country. European tools were in less variety and were more generally intended for a few standard applications.

The British "Universal Joiner" is a form of tool much less frequently seen in the United States. It consists of a combination of several tools mounted on a common frame. For example, a circular saw, a planing-machine, a molding-machine, a mortising and a tenoning machine, are frequently all made to form parts of a single complex tool. The combination makes a very compact machine, and its cost is less than would

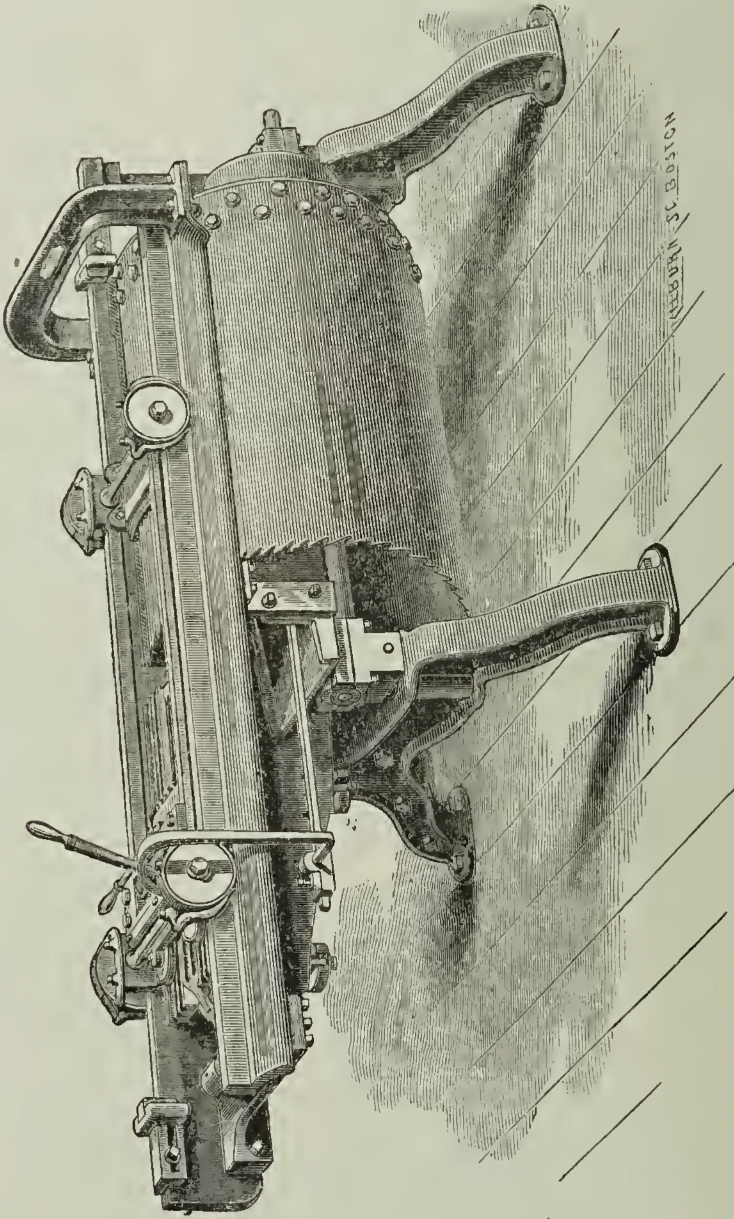


Fig. 123.—B. D. Whitney's cylindrical saw.

be that of the several machines if built separately. It would not suit the purposes of large establishments, but probably answers well for small shops. This was the most noticeable wood-working tool in the British section.

257. AMERICAN TOOLS—B. D. WHITNEY'S PAIL-MACHINERY.—Taking up this class of machinery in greater detail, space should be given for an extended description of the pail-making machinery of Mr. B. D. Whitney, which attracted more attention from visitors than probably any other collection of machinery in the exhibition, and which was remarkable alike for its ingenuity in general design, its richness in original details, and for the perfect adaptation of each machine to its special work.

There were two of these machines, one of which resembles, however, the universal joiner above described. The other machine was a cylindrical saw, (Fig. 123, page 248.) A steel cylinder, of the thickness proper for a saw-blade, and having teeth cut at the outer end, was carried at the extremity of a well-supported horizontal spindle. The length of the cylinder was somewhat greater than that of the pail for which it was to cut the staves, and its diameter such that it gave them the proper concavity or convexity of surface. Staves were first taken "in the rough" to the cylindrical saw, where, mounted upon a rest having a motion parallel to the axis of the saw-spindle, they were cut into shape. They were given the proper bevel by a saw mounted on the larger machine, the rest being mounted on a horizontal spindle, of which the center line held the same position relatively to the stave that the center line through the pail would have when the stave was finally fitted in its place.

The length of the stave was next made right by passing it between a pair of circular saws mounted on the same arbor; and finally the grooves for securing the bottom were cut by a revolving cutter in a lathe in which the pail was first put together in a hollow chuck, finished inside, the top edge properly beveled, and the upper hoop forced on. The bottom was turned and put in place, and the other hoops being driven on, the pail is taken out ready to receive the handle and then to go into the market. Somewhat similar methods are adopted in the barrel-making machinery made by the same ingenious mechanic.

258. In Mr. WHITNEY'S "GAUGE-LATHE," (Fig. 124,) for turning exceptional shapes, three cutting-tools are used: one for turning the stick to a rough cylindrical form; a second to rough out the irregular outlines wanted; and a third to smooth-finish it. The second cutter is caused to approach or recede from the line of centers by a templet, against which the tool-holder rests and along which it slides. The roughing-tools are of the usual **V**-shape. The finishing-tool is a long blade, set at an angle with the center line of the lathe in order to take a smooth shaving. Its edge is given such a shape that it finishes the work accurately.

The piece to be turned is supported between centers by a ring, and

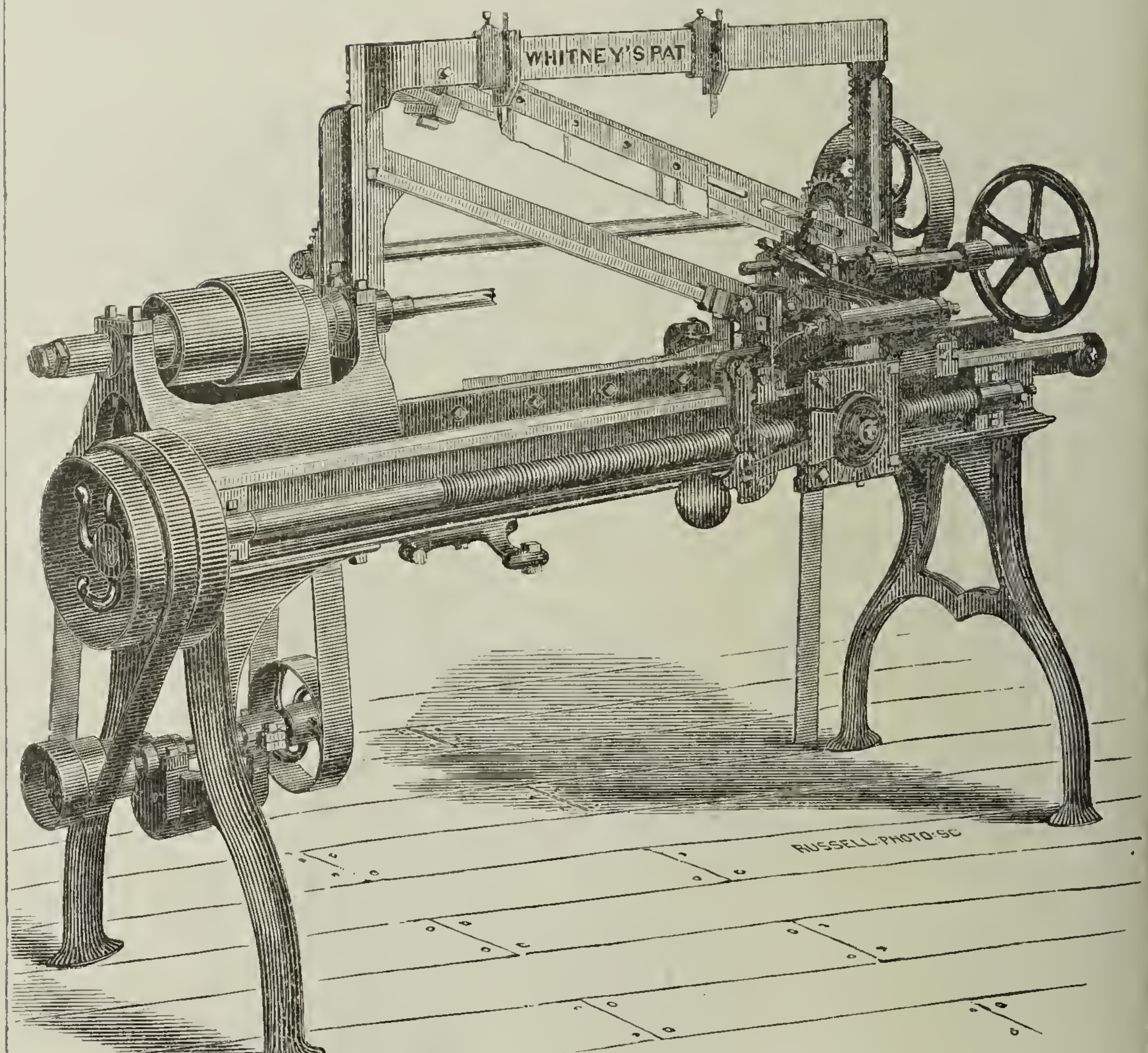


FIG. 124.—B. D. Whitney's automatic turning-lathe.

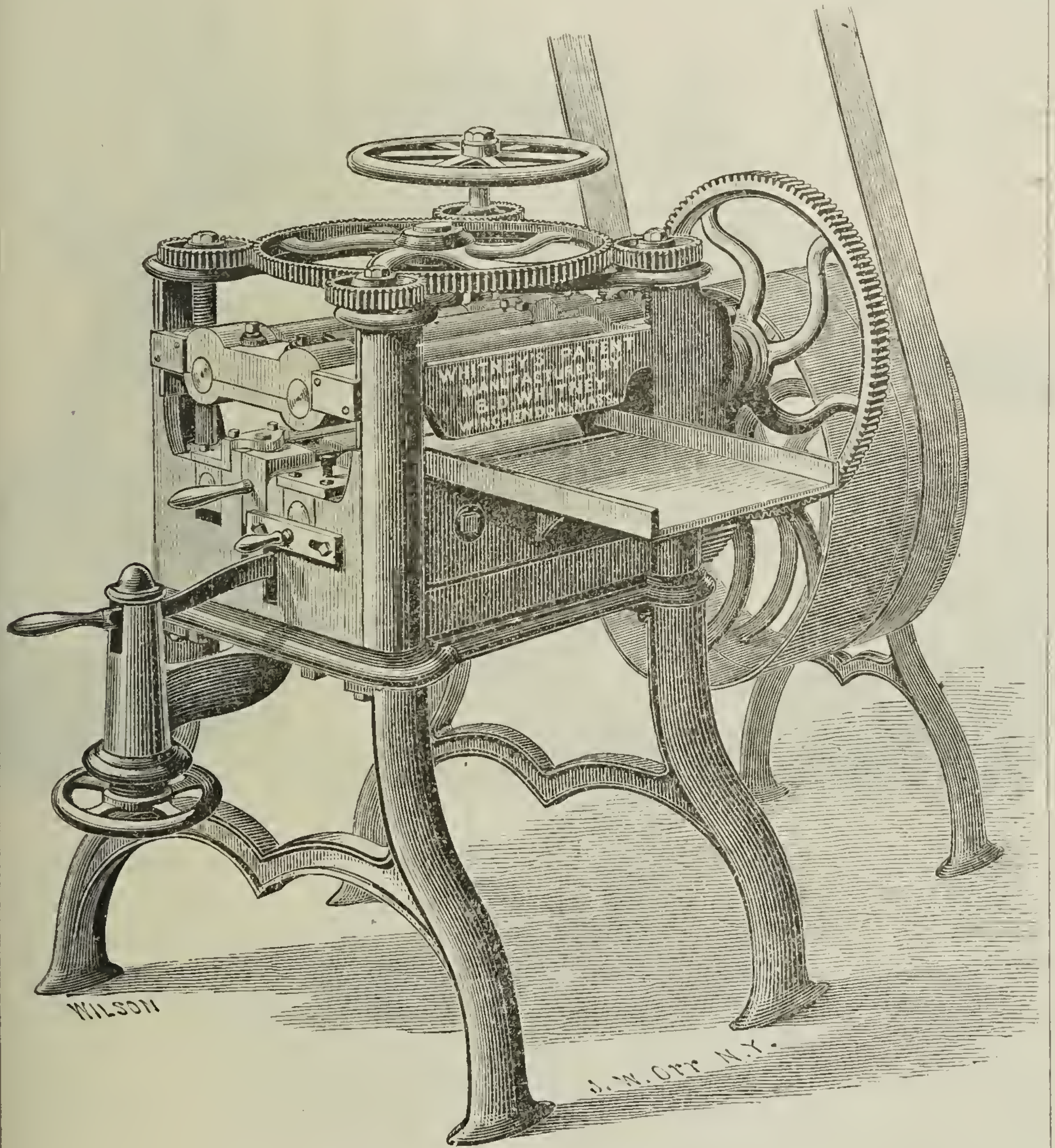


FIG. 125.—B. D. Whitney's smoothing-machine.

the workman is thus enabled to turn a comparatively long and slender stick. The movement of the slide-rest which actuates the cutters is checked at the end of its throw by a self-acting stop.

259. WHITNEY'S SCRAPER.—Another original design by the same exhibitor is his "scraper," a machine for giving a fine surface to hard woods, particularly where the grain is irregular. This is a planing-machine, in which the wood is carried by rolls suitably placed against a stationary cutter.

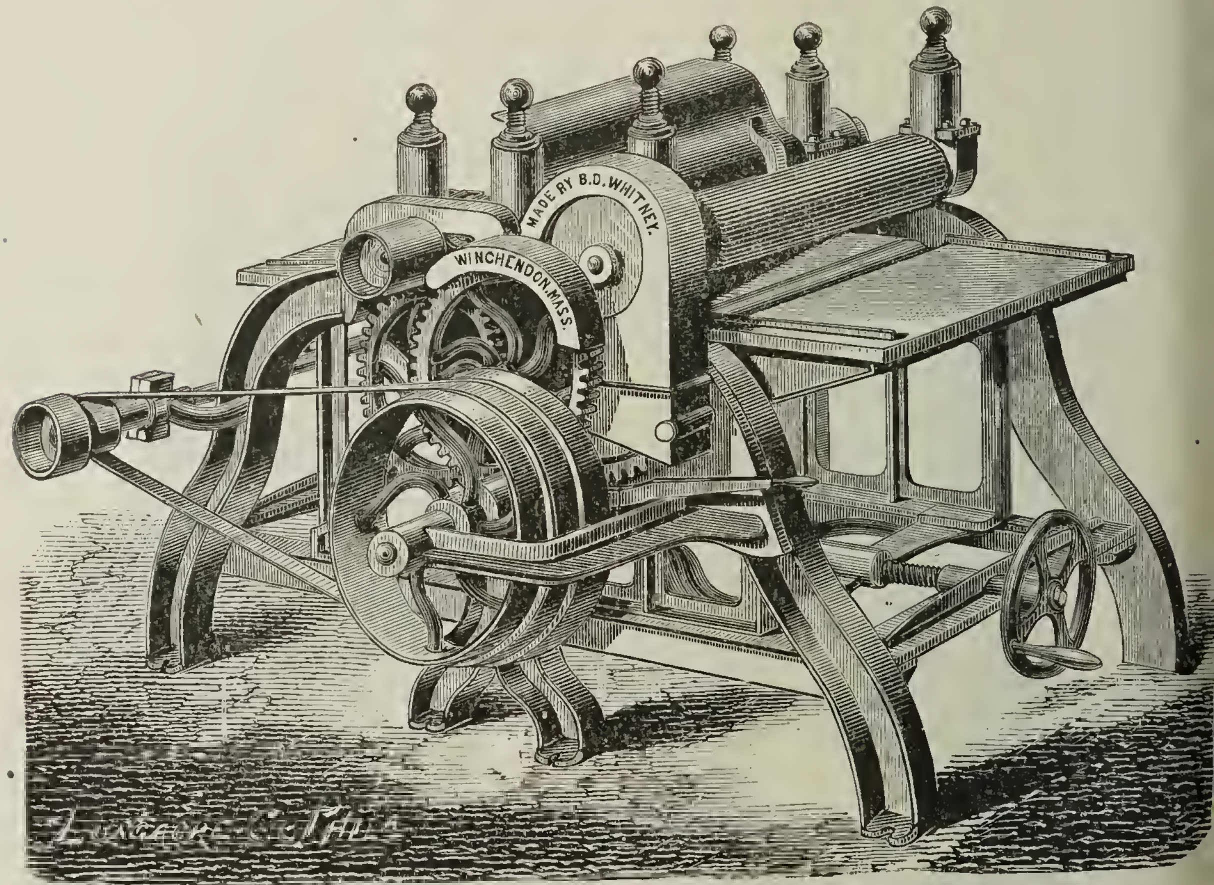

MADE BY B.D. WHITNEY.
WINCHENDON, MASS.

FIG. 126.—B. D. Whitney's cylinder planing-machine.

This cutter is a steel blade of sufficient length to extend across the machine, secured in a block of such strength as to be safe against springing. This blade is exceedingly sharp, and has the feather-edge which is generally considered essential in a scraping-tool for wood. The blade is very carefully set to take the thinnest possible shaving from the surface of the wood, which is given an ordinary good finish on the planing-machine before it is sent to the scraper. A little machine accompanies the scraper specially designed to sharpen the blade. It consists of a pair of emery-wheels, so set that one can bevel the edge of the cutter while the other squares up the face. The blade is clamped, during the operation, between a pair of jaws, which hold it firmly and precisely in position. As the sharpened blade passes from under these wheels, a stationary steel bar touches the edge, and, sliding along it, turns it, producing the feather-edge. Mr. Whitney states that this tool, if of good steel and well managed, will scrape several thousand square feet of hard wood without regrinding or resetting.

260. Several other tools—a neat little fret-saw, beautifully balanced; a tenon-drill, with table adjustable in all directions; a circular-saw bench carrying two saws, one a cross-cut, the other a rip saw, either of which can be brought into use as needed; and a planing-machine, with adjustable table—were in this collection, and were greatly admired by all who were capable of criticising them.

261. WHITNEY'S BAND-SAW.—The band-saw exhibited by Mr. Whitney has already been mentioned. It was thought by many the most thoroughly well-considered design in this department of mechanism to be found in the whole *Ausstellung.*

The saw was supported against the backward push of the work by a steel disk, set with its center at one side of the line of the blade, and kept slowly revolving by a little worm and gear receiving motion from the axle of the upper band-wheel.

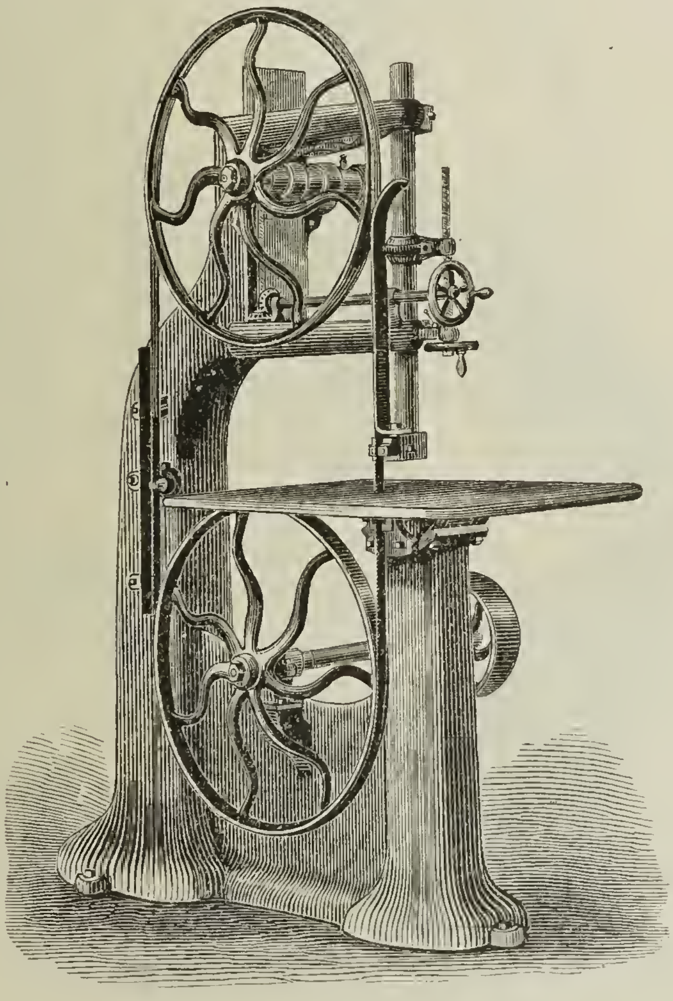


FIG. 127.—B. D. Whitney's band-saw.

The spring of the blade and the alteration of length due to change of temperature was provided against by hanging the upper wheel in a journal carried on a pivoted arm, the opposite extremity of which was sustained by a rubber spring. The arrangement was shown, by careful and repeated experiments, to be very perfect in action, and the uniform tension thus secured must have considerable effect in diminishing the risk of breakage of the saw-blade. The wheels carrying the band are usually overhung in such a manner as to create a side-strain, tending to cramp the shafts in their journals, and to cause heating, as well as to make it difficult to insure the blade against excessive and varying strains. In this example, the wheel was "dished" in such a manner (see Fig. 127) as to bring the line of pull on the blade into a plane passing through the center of the length of journal.

262. THE BAND-SAW OF MESSRS. RICHARDS, LONDON & KELLEY, of Philadelphia, was the only tool shown, built by that justly-distinguished firm. In neatness of design it excelled all others of its class. The frame was simple, strong, and stiff; the parts were well put together; the table had a convenient method of adjustment; the wheels were light, but stiff and strong; the expansion and contraction of the blades were provided against by a neat and handy adjusting-device. This design has evidently found favor abroad, for one of the best known English firms has copied it, and a fac-simile was shown in the British section, as already stated.*

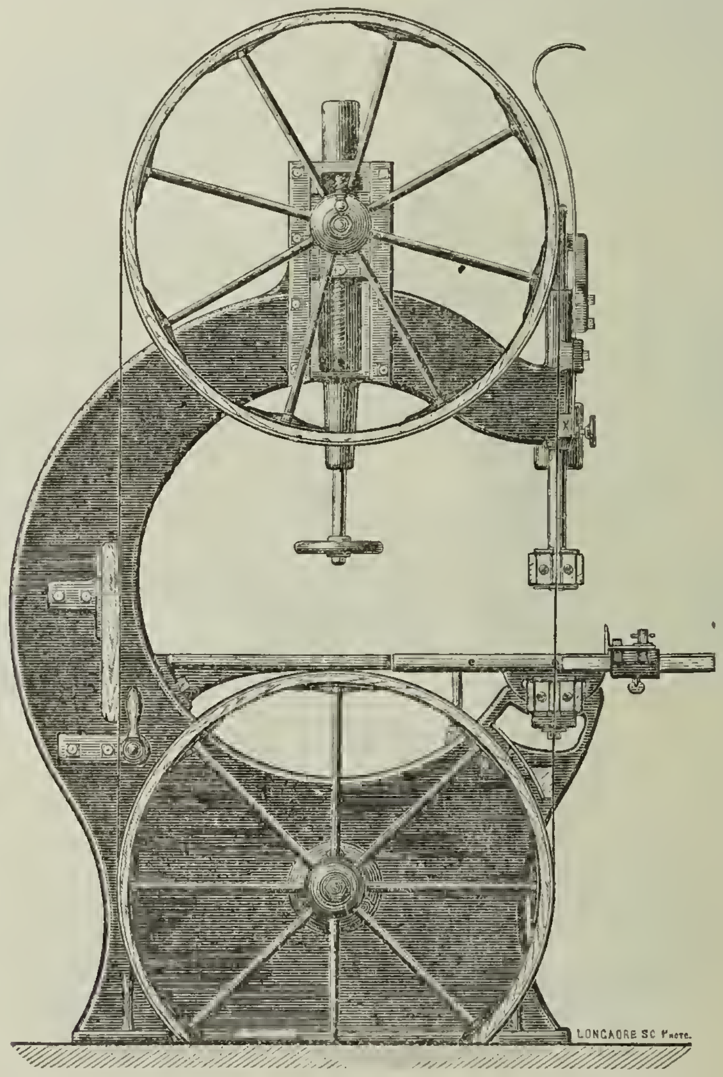

LONGACRE SC PHOTO.

FIG. 128.—Richards, London & Kelley's band-saw—side view.

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* A MAMMOTH BAND-SAW.—A band-saw, fifty-five feet long, sawing planks from a pine log three feet thick, at the rate of sixty superficial feet per minute—probably the most extensive experiment in log-cutting ever undertaken and successfully carried out—is the subject of the illustration herewith presented. No more forcible instance of the

263. THE INTRODUCTION OF THE BAND-SAW is one of the latest and most important advances in the history of machine-tools. Mr. Richards states that within the past ten years this introduction has occurred to such an extent that already thousands of machines have been made and sold by the comparatively small number of firms building them.

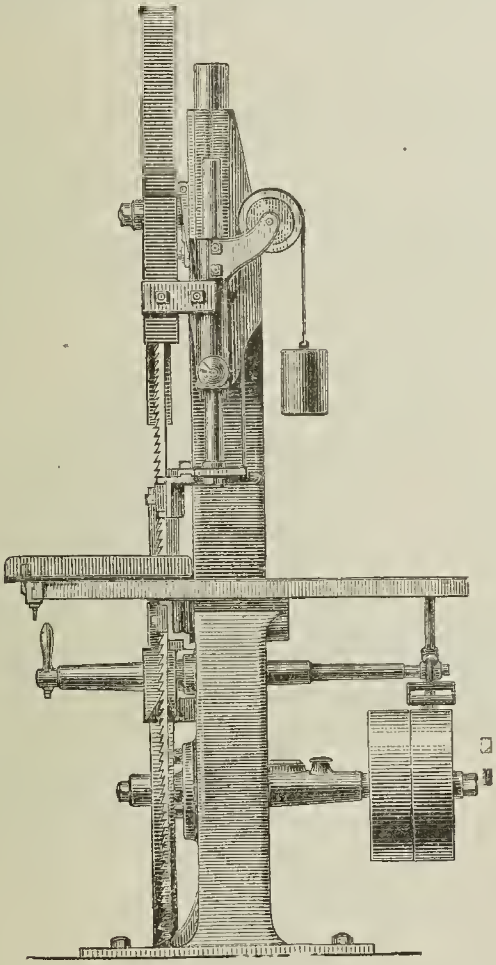

FIG. 129.—Richards, London & Kelley's band-saw—front view.

They were first invented in 1808, by a London mechanic, William Newbury, who is said to have made a very excellent machine, and one embodying the greater proportion of the devices which have made the modern machine so valuable. They were first introduced into the market and made commercially important by M. Perin, of Paris, who

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great capability of the continuous saw-blade can, we think, be adduced, nor its superior efficiency, as compared with the gate and circular saw, for the purposes indicated be better demonstrated, than by the details below given, obtained directly from Mr. J. J. Van Pelt, in whose mills (at the foot of Tenth street, East River, in this city) the immense machine has, for some time past, been employed.

The saw, which is 55 feet long, $4\frac{1}{2}$ to 6 inches wide, and of 16 gauge, was made by the celebrated firm of Perin & Co., of Paris, France, at a cost of one hundred dollars. The machinery was constructed from the drawings and specifications of Mr. Van Pelt, by Richards, London & Kelley, of Philadelphia, Pa. The pulleys are of 75 inches in diameter, including hubs of wrought iron, and are mounted centrally on the main column so as to equalize the strain of the saw and prevent its springing, and to economize its weight. They are covered with a lagging of pine, over which is glued an envelope of heavy harness-leather. The bearings for the wheel-shafts are 4 inches in diameter and 12 inches long, and are made of an alloy of six parts copper and one of commenced experimenting with them about the year 1850, and who finally succeeded in conquering the only seriously formidable obstacle to their complete success and general introduction—the difficulty of securing a perfectly reliable weld in the endless steel band which formed the saw. His success was first publicly acknowledged in 1867, when he received at the Paris Exposition the Grand Cross of the Legion of Honor.

264. M. Perin still holds the leading place, in the business of making these tools, in France; but the Messrs. Dougoujon are apparently rivaling him in the making of blades. Nearly all band-saw blades have been, until lately, made in Paris. They must be made of a special quality of steel, which has sufficient wearing-power to do good work, but which, at the same time, must be capable of welding firmly, and of sustaining subsequently the severe trial to which it is subjected, as it is alternately bent and straightened while doing its work. This is a combination of qualities very difficult to secure, and one which demands special grades of metal as well as a peculiar treatment, which can only be given by a skilled and experienced workman. Sheffield manufacturers are now taking up this business, and it will probably not be long before they will have secured a fair share of the trade.

265. The other firms mentioned above as exhibiting wood-working machinery presented, usually, good illustrations of the class of wood-working machinery which best suits the market of the United States, or of any country where wood is plentiful, capital expensive, and the demand for cheap and effective machinery very great.

The bad taste shown in painting some of these machines probably

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tin. The tension is from one to four tons, and necessarily calls for the greatest rigidity in the framing to prevent the guides from being thrown out of position by the varying tension of the blades.

The timber lies perfectly still upon the carriage and hardly requires dogging at the ends. The first cut is directed by adjusting the log as the saw progresses, after which the slab face is carried past permanent gauges, very much on the principle of common hand-slitting. The operation brings into play several ingenious devices for supporting, setting, and guiding the log, inventions of Mr. Van Pelt, to which, however, no special reference is here necessary.

The kerf of the band-saw is $\frac{1}{8}$ of an inch, or less than one-half that of a circular saw. Its speed is 4,500 feet per minute. We are informed that it cuts pine timber at the rate of sixty feet, and oak and yellow pine at thirty feet a minute, the logs being from one inch to five feet in thickness.

By far the most important advantage remains yet to be noticed. It is that the saw will follow the curvature of long timber, such as is used in ship-building and is cut with the grain. This not only causes no inconsiderable saving of material, but enhances the value of the work accomplished to such an extent that it is stated that deck-planks thus sawn are worth fully ten per cent. more than when cut by a circular blade. Another and more striking idea of its capability may be gathered from the fact that a board $\frac{1}{8}$ of an inch thick has been taken, without the slightest variation, from the whole length of a log 50 feet long and 20 inches through. In the establishment above referred to, we learn that from eight to ten blades are yearly expended, and that the cost of running is about the same as that of the ordinary forms of saws in common use.—*Scientific American.*

had some influence in awakening prejudice and creating adverse criticism; but it is more probable that the principal cause of the unfavorable verdict which many visitors undoubtedly rendered against some of them, after comparison with the more substantial and more expensively gotten up machines in the British section, was the impossibility of appreciating the circumstances under which they were intended to be used. For the market for which they were built, they are far better than the heavier, more highly-finished, and much more expensive foreign machinery.

266. HALL'S DOVETAILING-MACHINE belongs to the same class with the collection shown by Mr. Whitney—a special application embodying the evidences of "Yankee ingenuity."

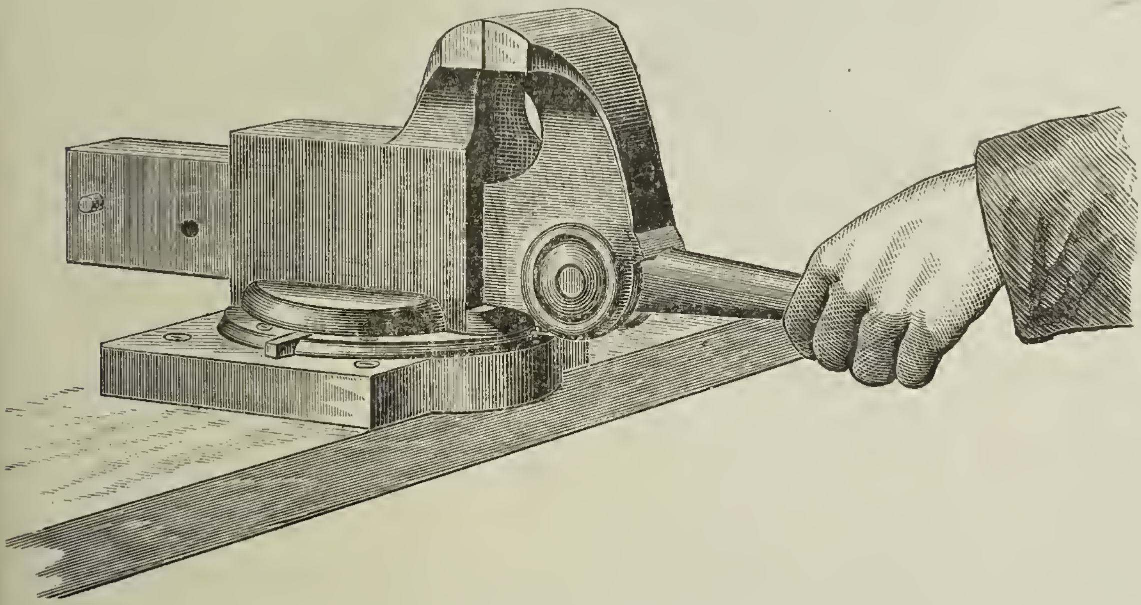


FIG. 130.—Hall's vise.

A set of revolving drills and cutters, with a single movement of the rest carrying the piece to be "dovetailed," do the whole work, and the dovetailed pieces fit into each other with an accuracy only attained in such work by automatic machinery.

A BENCH-VISE for metal-workers was also exhibited by Mr. Hall, which, by a peculiar and ingenious arrangement of simple mechanism, was made to grasp or loosen the work with a single movement of the hand. Fig. 130 shows the appearance of this vise as mounted on the bench and about to be used by the workman; Fig. 131 represents the vise with a piece of metal clamped between its jaws; and Fig. 132 represents a longitudinal section, and exhibits its interior mechanism.

P P is the plate by which the whole is secured to the bench; A and B are the jaws, the first movable by sliding inward and outward, and the second secured by the collar B B N. With the handle in position as shown, the jaws may be approximated or separated without obstruction, and to any desired extent. When the piece is placed between the jaws, as in Fig. 131, the jaws are brought snugly together to hold the piece, and the handle is then depressed, and the one motion causes the jaws to grasp the piece more firmly and to take positions from which no force or blow can dislodge them. The clamping-mechanism is the knee-joint R E G, which receives a support by the depression of the serrated piece G into contact with the serrations in H on the base. On dropping the handle, the lever J is elevated at K, permitting G to fall into action, and the same motion draws the bar D D outward, forcing E downward by the action of the wedge at that end. The spring L acts with the parts already described in restoring the parts to their positions, as seen in Fig. 132, when the handle is raised to loosen the vise. The vise turns freely to any angle on the bench when the handle is up, but when anything is griped, the vise cannot turn on the swivel.

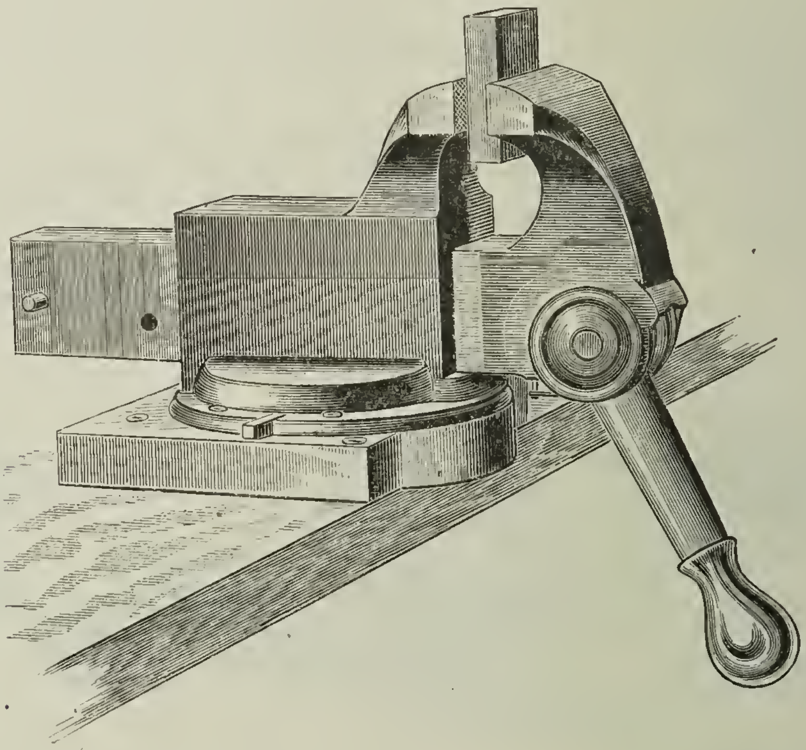


FIG. 131.—Hall's vise.

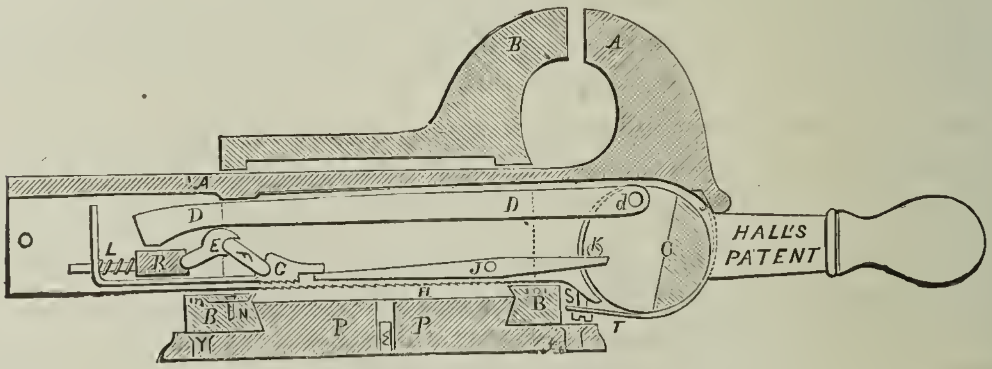


FIG. 132.—Hall's vise—longitudinal section.

In Hall's vise the farther the handle is depressed the greater the power. By drawing the wedge D more and more directly across the center C, and at the same time the gradual straightening of the toggle E F, the power to grip is increased much faster than the friction. The handle can be adjusted to operate as easily or hold as firmly as desired by screws S. The swivel can be tightened more or less by wedge W to suit any work. It can readily be placed on any bench without putting a bolt through, and can be used over drawers. Chips, filings, or dirt cannot get into it. Wear does not cause lost motion or injure the vise.

It is built of the best material, by machinery which produces numbers to gauge alike.

267. Messrs. J. A. FAY & CO., of Cincinnati, Ohio, exhibited some plain, serviceable, and comparatively inexpensive tools, such as are well adapted to the western market. The illustrations exhibit the form of these tools. Their band-saw attracted the attention of many visitors, particularly from the wooded districts of the Austro-Hungarian Empire, where the conditions of the market more closely resemble those of our Western States than probably in any other portion of Europe.

BAND-SAW.—This machine (Fig. 133) represented the medium-sized band-saw of J. A. Fay & Co., Cincinnati, Ohio, and is constructed for the more general purpose of scroll-band-sawing, being equally applicable to light or heavy sawing. The several novelties applied to the working parts of this machine are worthy of a description. The column is constructed of cast iron of a cored box-section, flanged, with the supports for the lower wheel and table webbed and flanged, all cast in one piece.

The lower wheel is 33 inches in diameter, of cast iron, and fastened to its shaft by a nut. This shaft has with its bearings both lateral and vertical adjustments, and upon it the tight and loose pulleys are placed.

The upper wheel is a combination of cast iron and steel, made very light, to reduce inertia and relieve the saw from the sudden strain in starting and stopping. The shaft of the upper wheel revolves in bearings which are adjustable for the guidance of the saw to its correct line on the faces of the wheels. The bearings of the upper wheel have also a vertical adjustment for different lengths of saws, and their support is flexible in its gibbed sides for variations in the expansion or strain upon the saw. This flexibility is maintained by the weighted lever acting upon the screw which raises and lowers the bearings of the upper wheel. The guides for the saws, one above and one below the table, are arranged to accommodate different thicknesses and widths of saws, and have behind the saw a steel wheel which relieves the back of the saw from all sliding friction. There is a combined shipper and brake, which act simultaneously, the brake being applied when the power is thrown off. The vertical bar which carries the upper guide is governed and re-

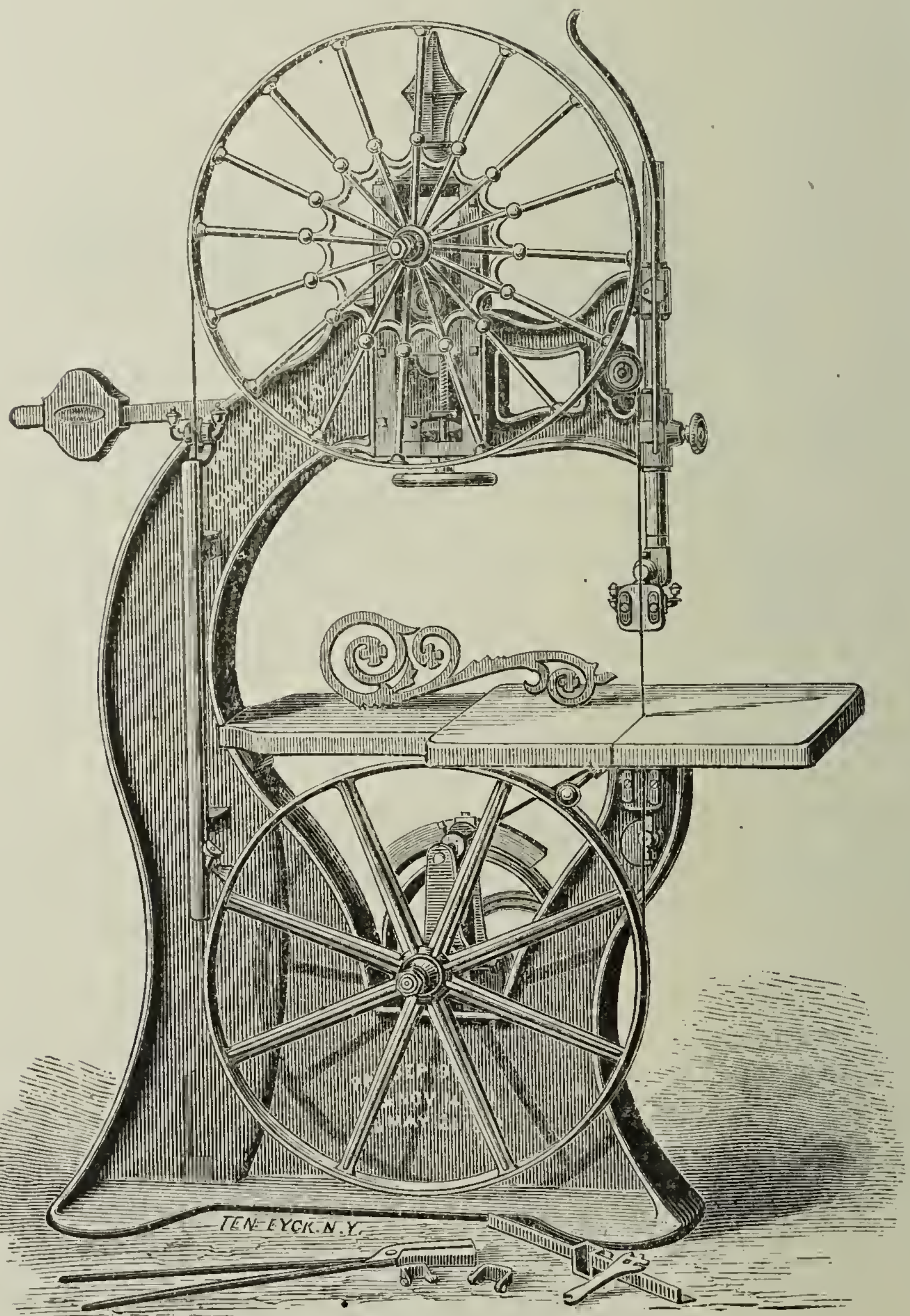


FIG. 133.—Band-saw, by J. A. Fay & Co.

tained in its position by a retracting spring, by which it is counterbalanced. The table is adjusted to an angle of thirty degrees, and is adjusted to return to a right angle with the saw.

No. 2. COMPOUND BED-MORTISING MACHINE.—This machine (Fig. 134) is adapted for work ranging from the lightest to a medium heavy class of mortising, and in its arrangement is equally applicable to all. The column has a heavy-plate front, with deep sides, well braced, and open at the back for convenient access to the reversing-gearing.

The driving-shaft is at the top of the column, and has upon it the pulleys and crank-wheel from which the chisel-stock receives its vertical reciprocating motion.

The bed is moved laterally under the chisel by a rack and pinion, with a hand-wheel for different lengths of mortises, and it can be set to mortise at any angle. The support of the compound bed is gibbed to the column, and can be raised and lowered by a screw actuated by a crank and bevel-gearing.

The treadle can be graduated to give greater or less lift to the bed by means of a segmental ratchet, into which a spring-pawl operates, giving the treadle a greater or less arc to move in, as the pawl may be adjusted, and this also changes the depth of the mortises.

An economic feature of this machine is the positive automatic reverser for the chisel. This is operated by a pawl, which is attached to a bar connected with the bed-support and treadle. The weight of the bed as it drops from its highest point is utilized in the last part of its fall by the pawl falling into a step, which revolves a series of segmental gearing, and in the alternate raising and dropping of the bed the chisel presents a reversed position toward either end of the bed. The chisel is held rigidly in its position, when reversed, by a detent which comes in contact with the connecting-bar as the bed is raised to the chisel.

BUILDERS' AND SASH AND DOOR MAKERS' TENONING-MACHINE.—This machine (Fig. 135) is for tenoning doors and sash or cabinet-work, being adaptable to these or any similar classes of tenoning.

There are four cutter-heads on this machine, two for cutting down the tenons and two termed cope heads, which are for shaping the shoulders of the tenon for molded or beveled edges. All the working parts are driven from one shaft. The main heads are driven by one belt, which is kept under proper tension by an idler-tightener, governed in its vertical movement by a balance-weight acting over a sheave-wheel, the whole being self-adjusting.

The main heads are adjustable separately, their supports being gibbed to a vertical stand placed at the end of the main frame of the machine. The lower head-support is attached to the upper support by a screw, by which the thickness of the tenon is gauged. The upper head-support is regulated in its height by a screw in the top of the vertical frame,

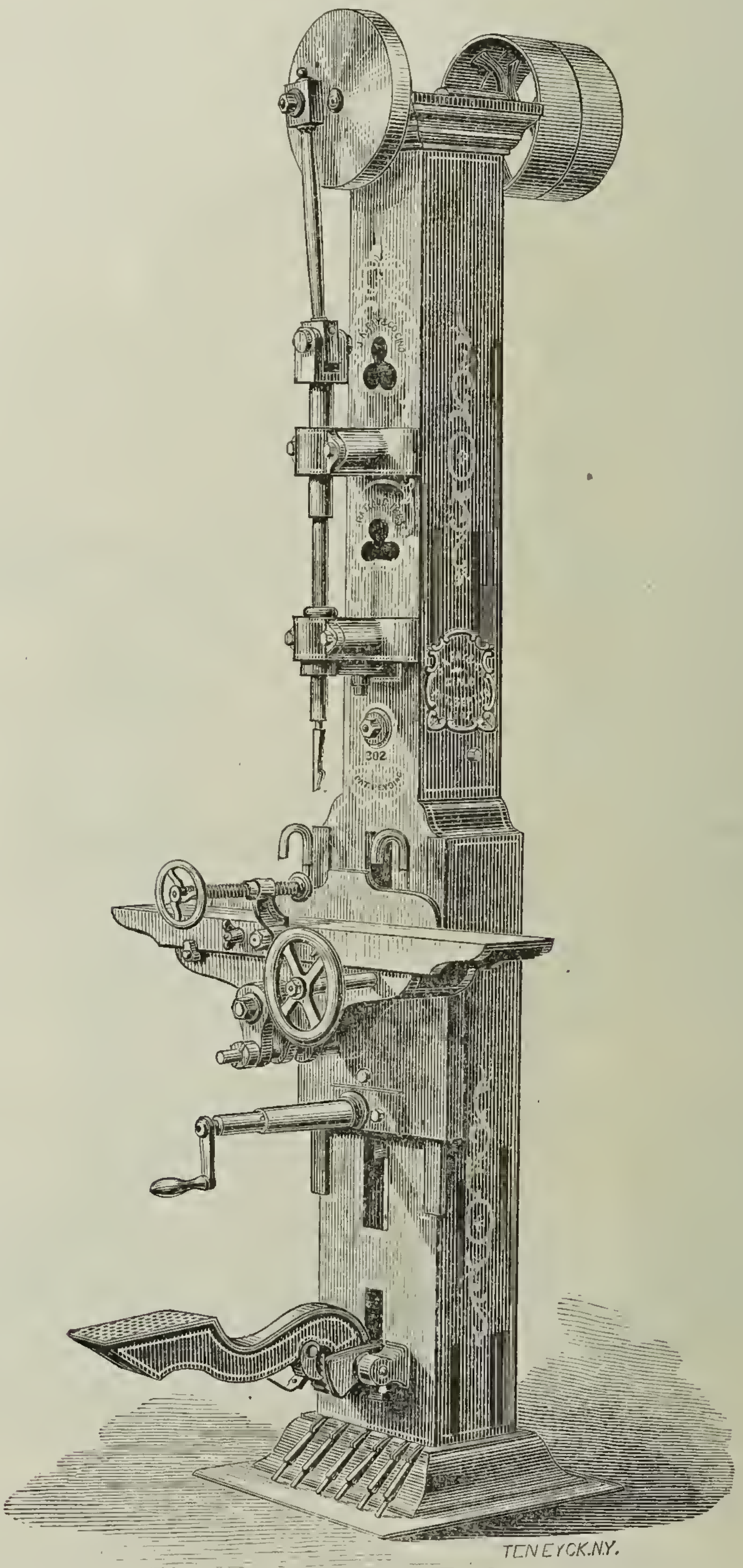


FIG. 134.—No. 2 compound bed-mortising machine.

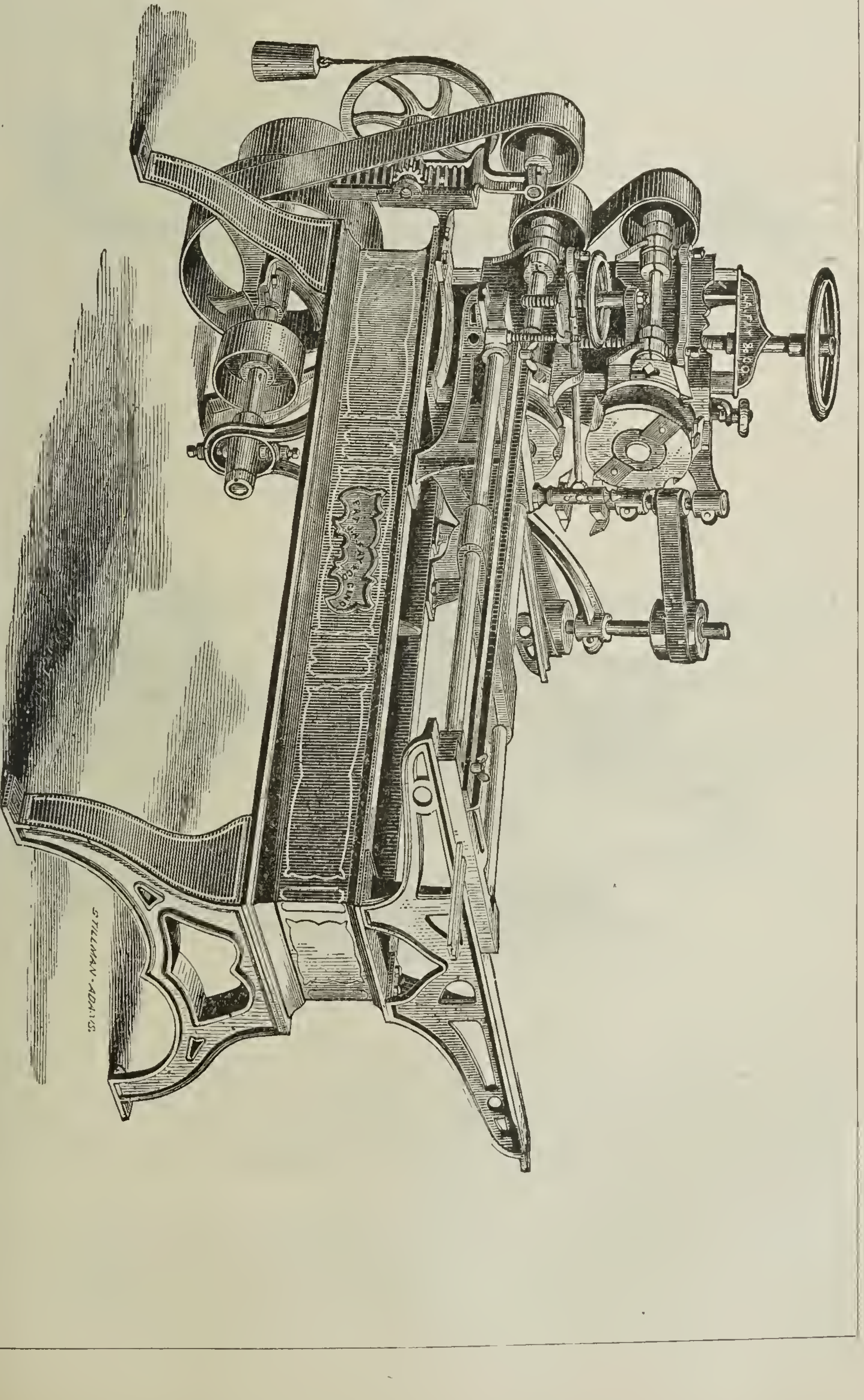


FIG. 135.—Builders' and sash and door-makers' tenoning-machine.

which also raises both heads simultaneously and gauges the depth of the tenon. The upper head-shaft has an end adjustment for making the shoulder longer or shorter.

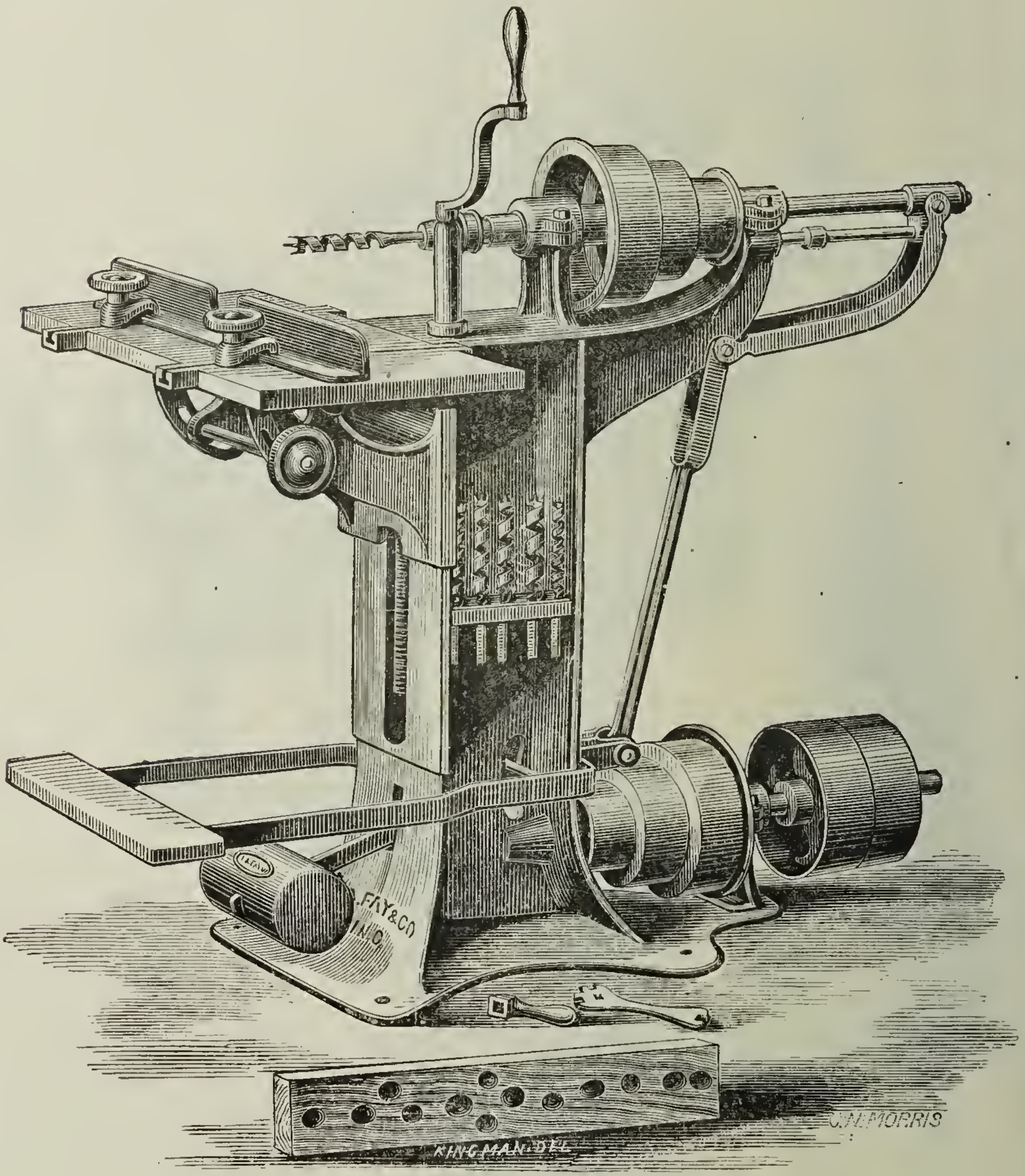


Fig. 136.—Universal horizontal boring-machine.

The cope-heads are moved with the main heads by the same arrangement, being fastened to the same supports and with separate adjustments on their own frames. The cope-heads are driven from a separate shaft at the back of the machine, which can be disconnected at will, and either pair of heads run separately.

The table remains upon the same horizontal plane, and is movable past the cutter-heads on planed ways. The table has stops to gauge the lengths and a lever for retaining the material in its position. It is arranged for tenoning at an angle, and in all its parts its adaptability is evident.

UNIVERSAL HORIZONTAL BORING-MACHINE.—This boring-machine, (Fig. 136) is one of a class most generally in use. The boring-spindle travels in a fixed horizontal line, the material being adjusted upon the table to the desired position or angle. The power is conveyed to the boring-spindle through the cone-pulleys, and the speeds arranged by the position of the belt upon them. The augers are held in the boring-spindle either by a universal chuck or held in the socket by a set-screw.

The auger is advanced to the work by depressing the treadle, and r ecedes by the action of a weighted lever attached to the treadle, which returns it to its proper position.

The table is raised and lowered by means of a screw, and is adjustable to any angle up to 45°, and held to its position by a hand-wheel screw. The fence upon the table is also adjustable to any angle or position upon its face by the bolts, which move in slotted grooves.

The column of this machine is of webbed flanged section and substantial design, and the general construction and finish of the machine shows it to be one of great power and usefulness.

268. BRITISH WOOD-WORKING TOOLS were, as has already been remarked, distinguished, like their other machinery, by their strength and solidity. They were given plenty of metal, strong frames, excellent forms, and the best of workmanship. They precisely meet the demands of the British market, as the tools found in the markets of the United States meet the demands for which they were created. The abundance of capital in Great Britain, the comparatively great amount of labor put upon their more expensive timber, and the general inclination, everywhere observed, to make work substantial and durable, which is a con sequence of this condition of the British market, cause the practice by builders of machinery to differ in a marked degree from that of our own tool-makers, who are compelled to deal with purchasers to whom money is worth from 7 to 10 per cent., and who work timber which is supplied plentifully and at a low price.

269. Messrs. T. ROBINSON & CO., of Rochdale, England, had a very extensive and very interesting collection of tools, which were excellent illustrations of the finest British practice.

Among these tools was one of the Armstrong dovetailing-machines, an invention which has, with justice, been considered one of the most valuable of those which British makers have imported from America. This tool consists of two circular saws carried on arbors so inclined that the two saws are nearly in contact at their lower sides, and are separated by some distance at the top. On the edge each disk carries its peculiarly-shaped saw, which cuts radially during a part of its revolution, and then, turning at right angles to the disk of the saw, the teeth cut in a line parallel to the axis. Thus they enter the wood, cutting the

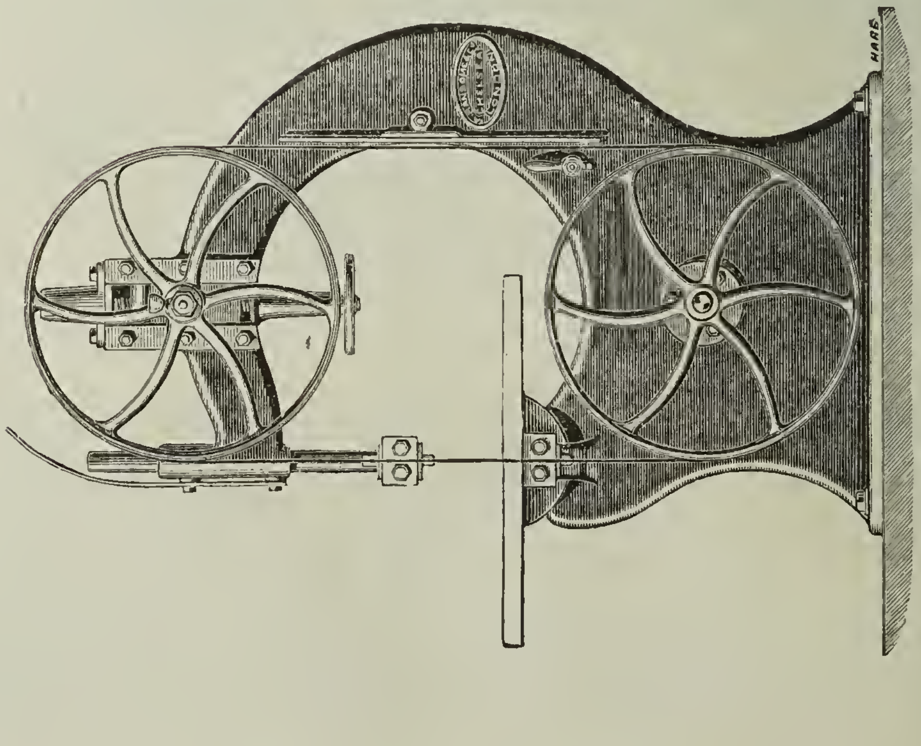


FIG. 137.—Plain band-saw.

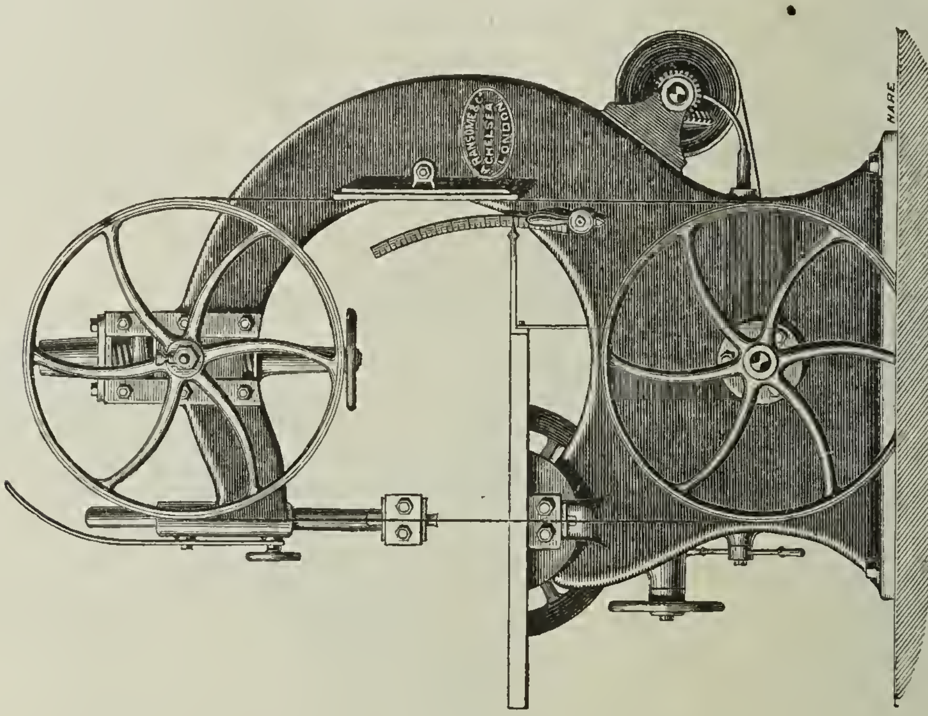


FIG. 138.—Band-saw with self-acting canting-table.

Saw-sharpening machine.

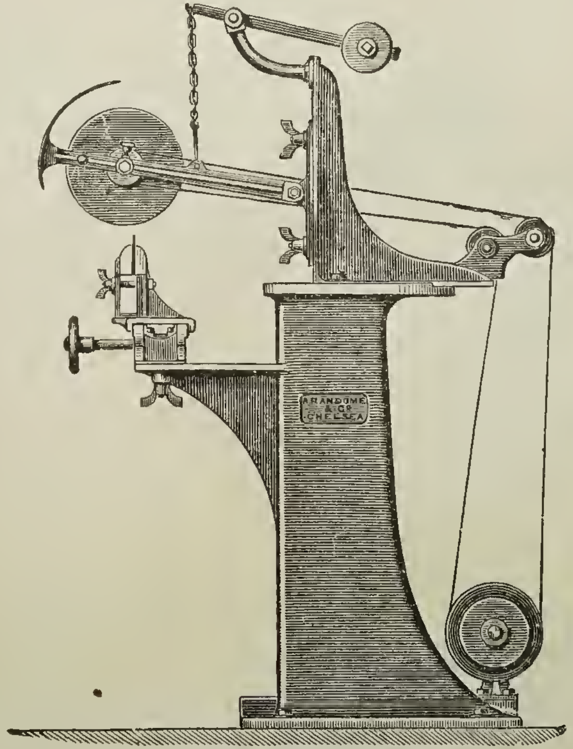


FIG. 139.—Side elevation.

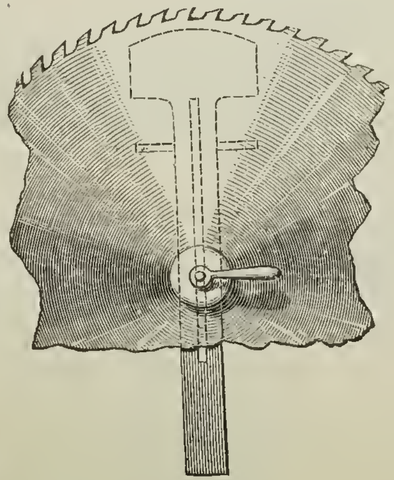


FIG. 141.

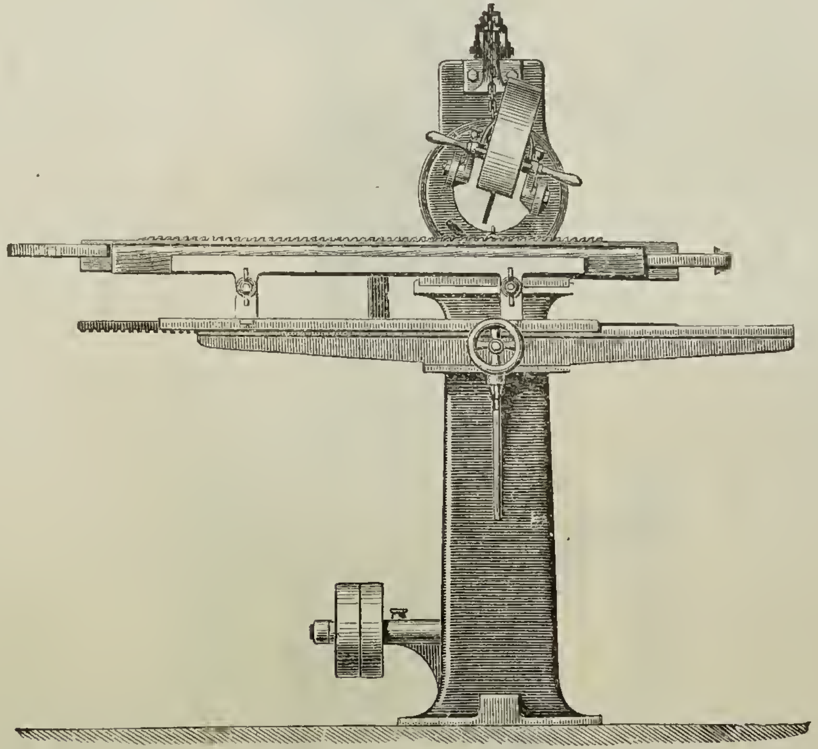


FIG. 140.—Front elevation.

flanks of the dovetail, and then, at the proper instant, the turned edge traverses the bottom of the opening. The saw-teeth are made on strips which are separate, and which are secured in place by screws on the disks.

A table carries the wood to be cut, and it is set to a gauge and fed across the saws by an automatic feed.

The machine is adjustable for any required number of dovetails, and by a reversal of the cutting-teeth it is fitted equally well to cut the pins.

This tool was beautifully made, and did magnificent work.

This firm exhibited one of the "general joiners" which have already been referred to, and one of the best exhibited examples. It contained a circular-saw, a band-saw, a molding and a tenoning machine, a boring and a mortising machine. Each tool is well fitted up, and can be driven independently. The latter is a decidedly better arrangement than that of some other exhibitors, who can only run one tool by starting up all, absorbing an excess of power, and causing a waste by wear and tear. On the molding-machine we noticed a device which seemed familiar; it was the method of adjustment adopted by Rogers, and the band-saw was, in some respects, similar to that of the American firm, Fay & Co., exhibited in the United States section; and our attention was called to the same device used by both for backing up the blade—a loose steel disk, which may continually change the line of bearing.

The independent mortising-machine was another well-made and excellent tool. The chisel works squarely and strongly, but the reversing mechanism is not as well arranged a device as some of the others. The frame and table are well put together, and all parts are nicely proportioned. The machine did good work. The molding-machines were equally good tools, with strong arbors, well-set cutters, heavy frames, and were readily adjustable for changing work.

Combined planing, chamfering, mortising, and boring machine.

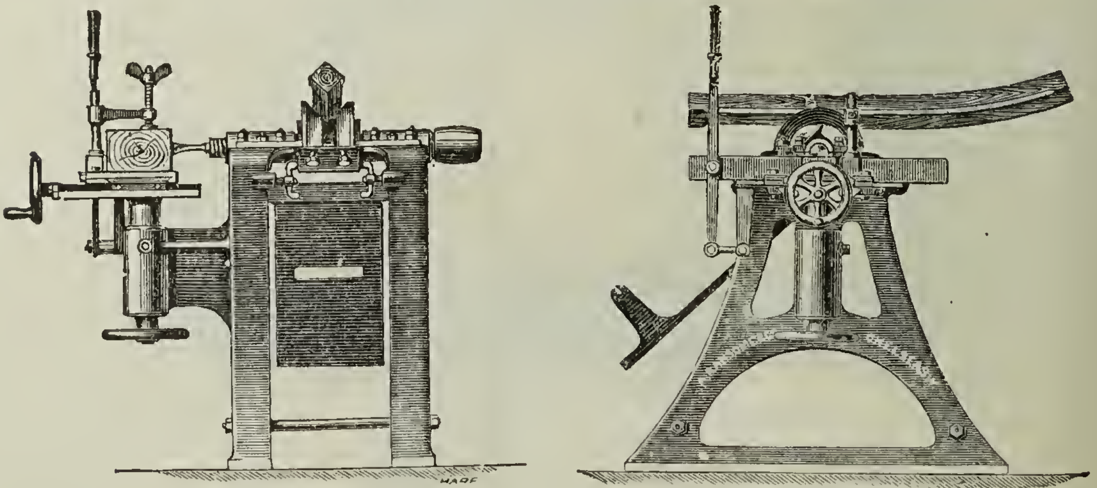


Fig. 143. Fig. 142.

One of the tools which attracted most attention from mechanics, and which was evidently regarded by the makers themselves as one of their best machines, was a "semi-portable log-frame," of which style there

FIG. 144.

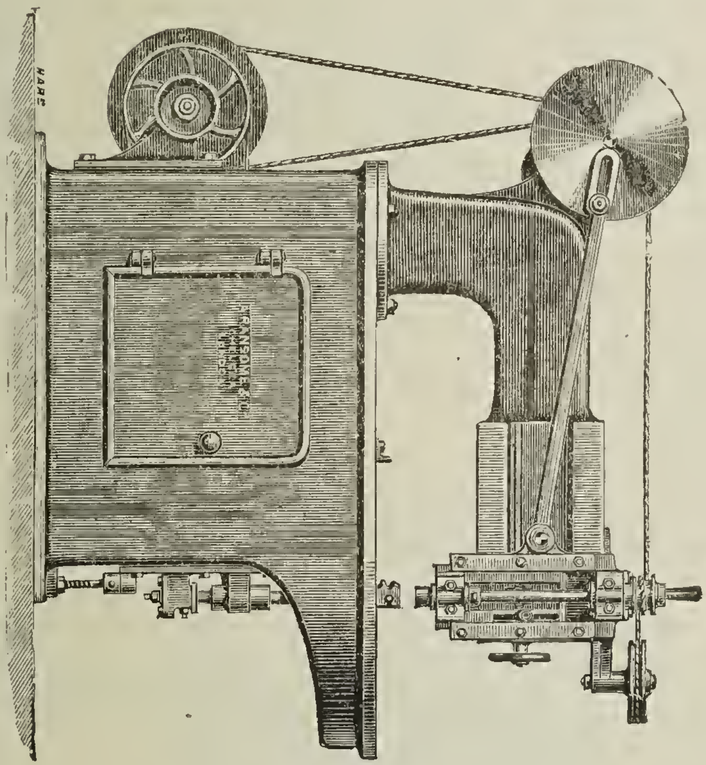
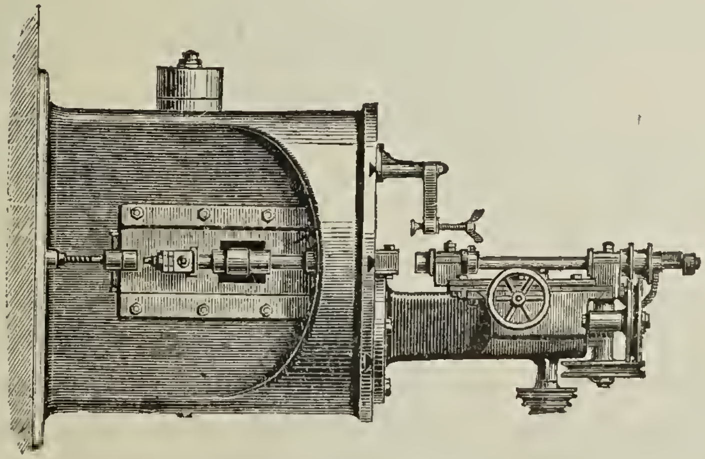


FIG. 145.



Universal molding, shaping, and recessing machine.

were several other excellent illustrations in the other exhibits of this section.

The saws were carried in the usual vertical saw-frame, which was mounted in a set of cast-iron vertical guides, which are rigidly and strongly secured to the bed which carries the table. The whole machine is, as the builders say, "self-contained," and can be carried about like one of the more familiar portable steam-engines, which are also termed "portable." It requires no foundation, and those exhibited were simply laid down upon the floor of the machinery-hall. A set of balance-weights is one of the essential features of the machine, and they are so well proportioned and set that hardly the lightest shake can be detected while the machine is in motion. The feed-motion is strong and adjustable to all the work of the machine, which is intended for cutting both logs and boards up to widths of thirty inches. This saw-frame was of wrought iron and well put together.

A band-saw and a fret-saw exhibited in this collection were plain tools, well made, but not as good illustrations of the best work of the firm as the other tools.

279. Messrs. RANSOME & Co. exhibited some of the finest tools in this section, and among them was prominent the band-saw, similar to that built in the United States by Messrs. Richards, London & Kelley, and other tools of designs resembling those familiar to our manufacturers. The band-saw, being a duplicate of that in the United States section, requires no description here. The same packing-boxes for holding the blade in line, the same steel backing, with the tallow-reservoir, and the same proportions are seen in both.

In securing efficiency in the band-saw, and combining rapidity and accuracy of operation with small expenditure of power, the following requisites are aimed at by Messrs. Ransome & Co., and are attained successfully:

A strong, heavy frame; a minimum diameter of wheel of 30 inches for small saws, 42 inches for saws of 2 or 3 inches width of blade, and of 6 feet and upward for saws of 6 inches width; wheels turned inside and out to secure a perfect balance; pulley-covers of well-fitted leather, and an arrangement for adjusting the position of the saw-blade on the pulley-wheel; adjustable guides to support the saw at the sides and to back it behind; an arrangement by which these guides may be fitted to saw-blades of various sizes; capacity of adjustment for saws of various lengths by raising or depressing the top pulley; a method of keeping a constant strain upon the blade, as its length is altered by changing temperature, using a spring or a weight; saws of uniform dimensions in cross-section, size and shape of tooth, and of uniform temper.

The hollow standards, the peculiarly roomy table, and the methods of adjustment already referred to when considering the same form of machine as exhibited by Richards, London & Kelley, of Philadelphia, are admirably adapted to securing these *desiderata*.

The plain machine (Fig. 137, page 266) is used for all ordinary sweep-cutting. The machine (Fig. 138, same page) with canting table is extremely useful for sawing out pieces of varying bevel. These machines are all supplied with Perin's blades.

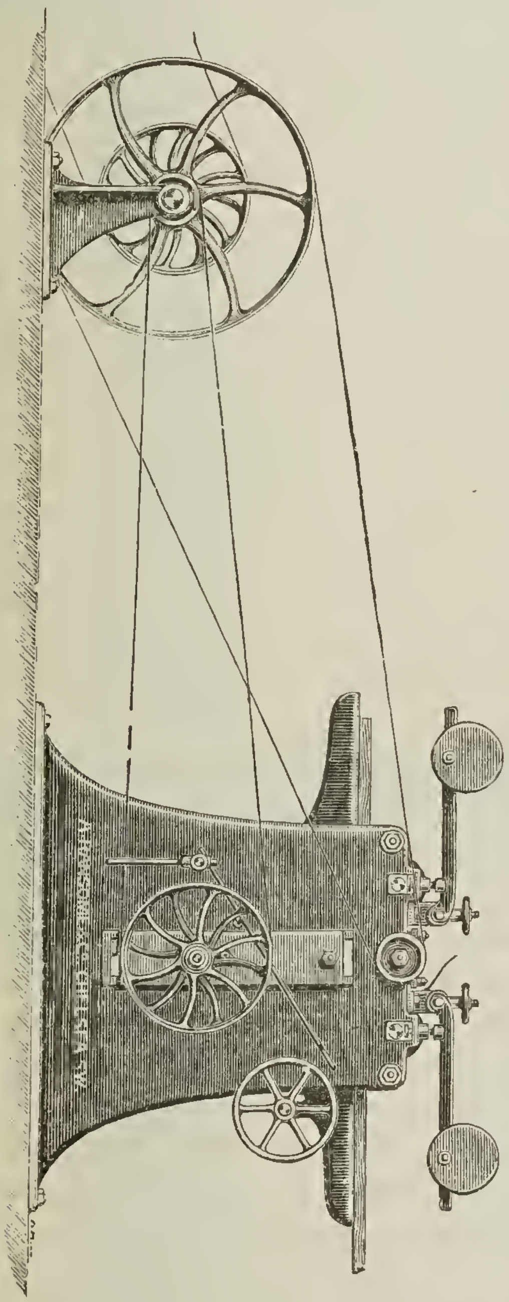


Fig. 146.—Panel-board-molding machine.

The saw-sharpening machine of this firm is a neat and valuable tool. This machine sharpens saws by means of a revolving emery-disk, and is fast superseding the old plan of sharpening by hand with files. It will top, gullet, and bevel either frame, cross-cut, or circular saws, with any form of tooth, so as not to require touching with a file. The grinding-disk works in a counterbalanced swinging carriage, which is brought down by hand to the saw, as required. This carriage can be set at any required angle, so as to give any amount of lead to the tooth, and the same disk can be used for gulleting, topping, or beveling. Members of the International Jury were informed that wheels for this machine had been made of the new Ransome artificial stone, with excellent results. The engravings (Figs. 139, 140, 141, page 267) show the machine as set for sharpening frame-saws, the saw being held in a cast-iron vise, which is moved along under the disk with a rack-and-pinion motion, worked by a hand-wheel. Another vise, shown separately in the wood-cut, is provided for circular saws of any diameter up to 6 feet. Both these vises work on a pivot, so as to give the tooth any required bevel. Fig. 139 is a side, and Fig. 140 a front elevation. Fig. 141 is an enlarged view of the saw.

The experience of firms who have adopted these machines, as the makers claim, shows the following results:

(1.) An enormous saving in labor, as a man at the machine will do as much work as six men sharpening by hand.

(2.) A saving equal to the whole cost of the saw-files formerly used for sharpening by hand, each disk costing only a few shillings, and lasting in constant work for about two months.

(3.) An advantage in having the saws always of the same depth in the gullet; for whenever a saw is sharpened at the machine, it is always gulleted in the same proportion.

Besides the above advantages, it is said to be found in practice that the action of the disk positively hardens the cutting-points of the teeth, and the saws last considerably longer in consequence without being sharpened.

Ransome's combined planing, shaping, chamfering, mortising, and boring machine is a beautiful little tool, which does good work on either straight or curved pieces. It is shown in Figs. 142 and 143, page 268, in end view and side elevation.

It is specially suited for planing, shaping, chamfering, and mortising the framing of wagons, carts, and machines constructed of timber, and it will work any kind of timber with equal facility.

The cutter-spindle runs in two pairs of very long, self-lubricating bearings, and revolves below a light cast-iron table, having a slot through which the cutters work. The wood to be planed is passed over the table, and the cutters produce a very fine surface. The table works on a hinge, and when not required it is turned over out of the way, as shown in the wood-cut. When set for chamfering, two circular angle-brackets are fixed over the cutters, and the piece is laid between them with the edge downward. The angle-brackets can be fixed at any distance from each other, and the cutters remove as much of the wood as falls below the aperture between them. The mortising and boring arrangement is similar in construction to that of the "general joiner," and it will make mortises or bore holes in any kind of timber with great speed and accuracy. Two lads can work at the machine at the same time, one mortising or boring, while the other is planing, shaping, or chamfering. A pair of collars are frequently attached to one end of the spindle to take a small saw for ripping, cross-cutting, or grooving, in which case a table made of hard wood is mounted on the mortising-

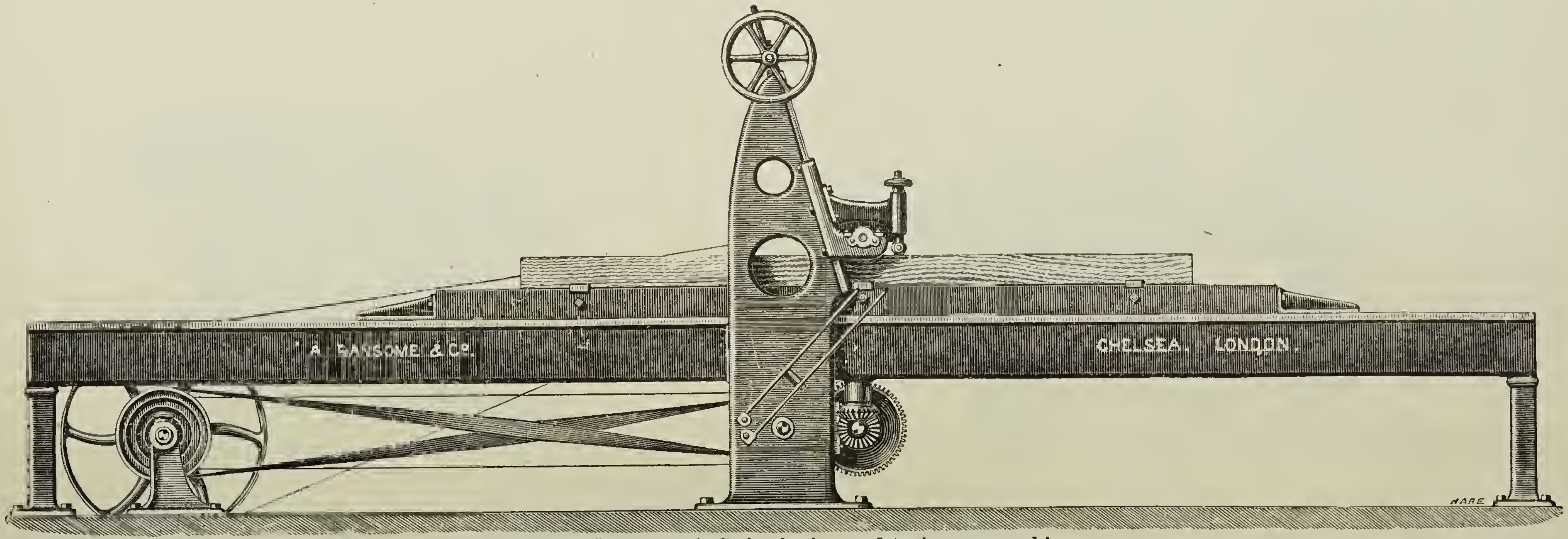
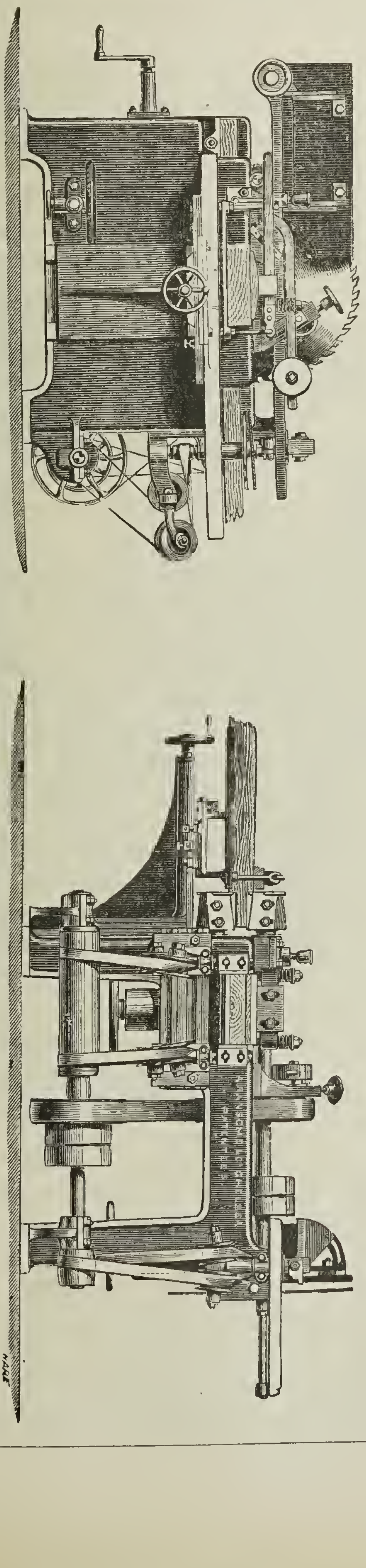


FIG. 147—Ransome & Co.'s planing and trying-up machine.



Figs. 148, 149.—Ransome & Co.'s "complete joiner."

slide, and thus serves as a small saw-bench with a rising and falling table.

The universal molding, shaping, and recessing machine is adapted to cutting circular or twisted moldings, sticking circular and straight sash-bars, molding, rebating, and grooving straight or curved frames, and many similar kinds of work.

The cutter-spindle is mounted on a slide, as seen in Figs. 144 and 145, page 269, and driven like the cutter in a shaping-machine as built for metal-working. The amount of travel is readily adjustable, and the tool is fed downward by the usual feed-device.

The panel-board-planing machine (Fig. 146, page 271) is intended for planing and surfacing thin boards and panels, and leaves the surface as smooth as if finished by hand with the smoothing-plane. It takes boards two feet wide and up to two inches thick. It is applied to railroad-car work, door-paneling, and to smoothing up small work of all kinds.

The cutters are screwed to a long wrought-iron adze-block, having a spindle of mild-centered cast-steel running in self-lubricating bearings specially constructed for high speeds. The boards are fed through the machine by two pairs of rollers, all of which are driven, and being perfectly smooth, they do not mark the surface of the wood. This allows boards, after being planed on one side, to be turned over and again passed through to plane the other side, without sustaining the slightest damage from the rollers.

The pressure-apparatus is so arranged as to hold the board firmly close to either side of the block, thus preventing any vibration in it while under the action of the cutters.

The rate of feed can be varied instantaneously while the board is passing through the machine by the two diagonal levers shown in the engraving, which also stop and start the feed, and the table can be readily adjusted to suit for boards of different thicknesses by turning the hand-wheel which is shown in front of the machine. The rates of feed range from 15 to 30 feet a minute.

The planing and trying-up machine (Fig. 147, preceding) is intended for truing-up carpenters' and joiners' "stuff," and to produce a very smooth, finished surface. The cutters are carried by a wrought-iron "adze-block," driven at high-speed.

The spindle is of steel, and runs in long bronze bearings. The spindle is hard on the exterior, but inside is of a soft temper, thus, as the makers claim, combining stiffness with toughness, and giving an excellent bearing-surface.

The "brasses" are very accurately made and fitted. The bottom brasses are slotted on the lower side, and a piece of felt is inserted in this slot, and extends downward into a large oil-chamber. Oil-grooves lead the oil back from the bearing into this chamber, and a free-flowing and uninterrupted lubrication is obtained, which is the more rapid as the speed increases.

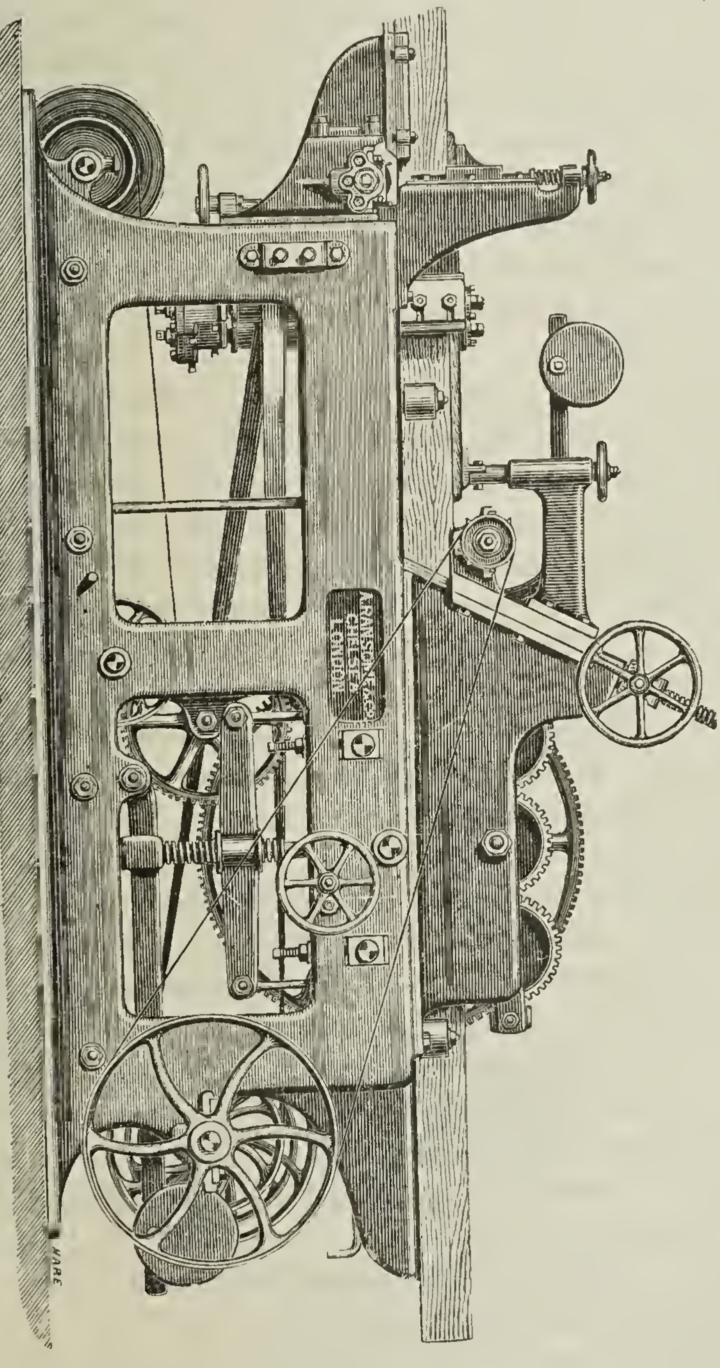


FIG. 150.—Combined planing and moulding machine, (large size.)

Both feed-rollers are driven, and the rate of forward feed may be varied from 10 to 30 feet per minute; the return-motion is about 40 feet per minute. The feed may be adjusted at any moment, and while the machine is in motion, by shifting the diagonal levers seen at the side of the tool on the upright. These levers also stop, start, and reverse.

Messrs. Ransome & Co. exhibited a good type of "complete joiner," (Figs. 148, 149, page 273) which is, however, peculiar to themselves. It contains a well-set circular saw, strongly driven at 1,800 revolutions per minute, and fitted with a fence, which is so attached that it can be readily set aside when the saw is used for cross-cutting and the whole table-top is required clear. The molding-machine is well put together. It can trim all four sides of the piece at once, and the tools and feed are well driven, enabling heavy cuts to be taken. It takes in timber 7 inches by 4. The cutters make 4,500 revolutions per minute. The tenoning-machine is equally well arranged, and the whole makes a strong, handy, and efficient machine.

The saw-spindle is entirely distinct from those which carry the planing and molding cutters, and hence the operations of sawing and planing or molding can be carried on simultaneously or separately, as at two distinct machines. The saw-table rises and falls for grooving, rabbeting, &c., and is fitted with an improved fence, which can be set at any required angle, and is hinged so that it can be turned over at the end of the table when it is required to use the saw for cross-cutting. The planing and molding apparatus is permanent, and is thus always ready for work. The top and bottom cutter-block spindles are supported in bearings on each side, which insures great steadiness, and enables the machine to turn out very clean work. The wood being planed or molded, is fed through by a pair of revolving feed-rollers, both of which are driven, by which means a greatly-increased propelling-power is obtained. The top feed-roller rises and falls to suit the irregularities in a rough board, and at the same time it always exerts its full feeding-power. The rate of feed can be varied according to the nature of the wood being operated on. Tenons are formed by cutters, which finish them much more accurately than is the case where saws are employed for this purpose. Double tenons are cut and the shoulders scribed, at one operation, by a "drunken" saw and cutter-disk attached to one of the upright cutter-spindles, as shown in the wood-cut. Tenons can be formed with shoulders of unequal lengths by simply shifting the position of one of the tenoning-blocks on its spindle.

All of the cutter-spindles are of the best mild-centered cast-steel, and the bearings are specially constructed to stand high speeds, being fitted with a self-lubricating arrangement.

The planing and molding machines of this firm (Fig. 150, page 275) are among the best, if not the very best, in the Exhibition. The two exhibited were capable, respectively, of taking timber 12 by 4 inches and 7 by 3 inches in section. The builders state that they make three other sizes, varying from 16 by 6 inches down to 4 by 2 inches.

The feed-table carries a guide for the timber; the pressure-bars are weighted, except a bridge pressure-bar, which is set down by screws. Where the table extends beyond the lower cutter, it may be let down, turning on a hinge, and thus ready access obtained to the knives. There are four feed-rollers—one fluted, the remainder smooth—all driven from a pulley fitted for four speeds. There are top, bottom, and side cutters, which may be worked simultaneously on all four sides of the piece. These cutters are all readily accessible. The rate of feed may be varied from 12 to 35 feet per minute.

The tenoning-machine is one of the best of this fine collection of exhibits. It is simple in construction, the cutters well balanced, and driven strongly and at high speed. The feed-table is light, but quite substantial, and is carried on friction-wheels between guides. The tenons can be cut without laying them out by measure, after proper adjustment.

The distance between the upper and lower cutters is adjustable by two hand-wheels, one of which raises both, and the other of which alters their distance apart.

In all of these machines in which the cutters are driven at high speed the practice of Messrs. Ransome & Co. seems somewhat in advance of their competitors, and, in speed of cutters, they are fully up to the most radical among our own makers. They in some cases drive their cutters at 5,500, and even 6,000 revolutions per minute.

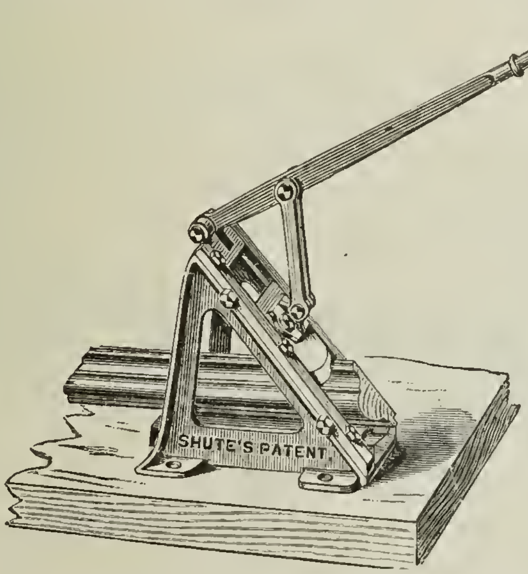


FIG. 151.—Shute's mitering-machine.

In adopting these speeds they have evidently been made familiar with the ordinary difficulties of balancing, of effective lubrication, and of attaining absolute security of connection of all parts. They have succeeded remarkably well in securing smooth motion of tool and feed, large, well-adjusted bearing, and great stiffness of framing. Low steel is used for centers. It was not stated whether they were, as they should have been, ground to shape. The firmness with which the work is held in these machines is an essential and well-maintained feature.

The mitering-machine (Fig. 151) is of the form known as Shute's. It is neat in design, compact, well arranged, works excellently, and is, as the writer is informed by engineers familiar with the British market, in extensive use. The makers state that they have sold one thousand of them. This is one of the tools which one of the German builders has copied as exactly as others have duplicated several American tools.

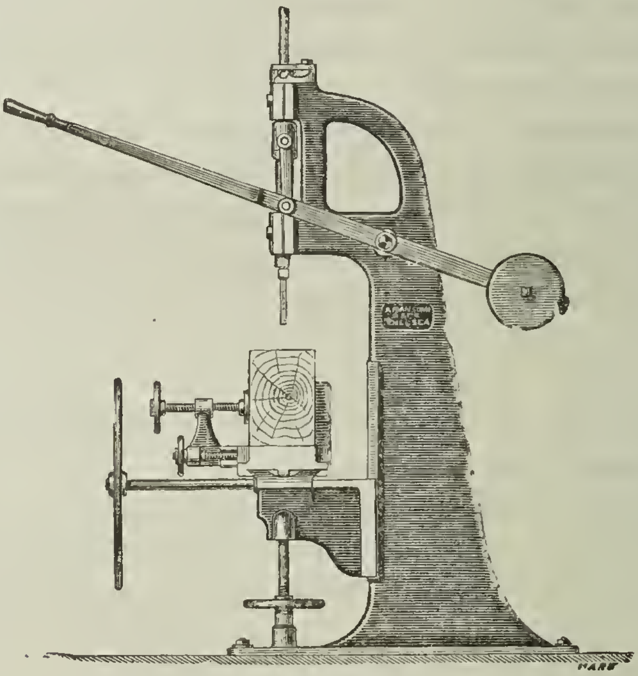


FIG. 152.—Hand-mortising machine.

An excellent hand-mortising machine (Fig. 152) is another of the neat tools here shown, Its table is capable of moving in any direction, and has its bearing precisely below the chisel, thus obtaining a firmness of support which could not otherwise be attained. The chisel has a reversing motion, and its supporting-bar is counter-weighted. It did good work.

A larger machine, (Figs. 153, 154,) driven by power, was exhibited, which is one of the finest tools of the kind seen at Vienna, and is, in general form, that of Richards, London & Kelley, of Philadelphia.

The chisel is fixed in a sliding bar, driven by a crank-wheel below by means of a strong connecting-rod. It has a hollow back and wings, which clear the hole perfectly. It is reversed by a cord carried on a pulley mounted on the spindle, much as a planer feed-wheel is arranged, this cord being driven by a pulley on the driving-shaft. Check-studs limit the range of rotation, and its operation is exceedingly beautiful.

The table has motions in all directions, and the work is adjusted by its motions. The chisel makes 600 blows per minute.

Ransome & Co.'s portable log-frame (Fig. 155) is a strong and well-designed saw-frame. Fifteen saws are carried as a maximum, and they can be set so as to cut up logs 14 inches in diameter. The frame is well balanced, and runs very smoothly. It is driven by two rods, one on each side the machine.

FIG. 153.

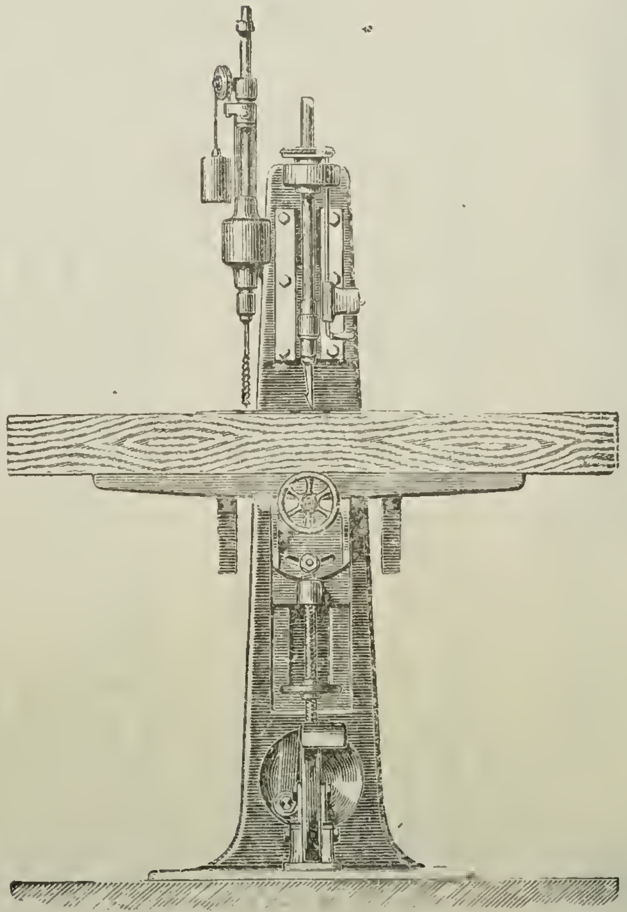
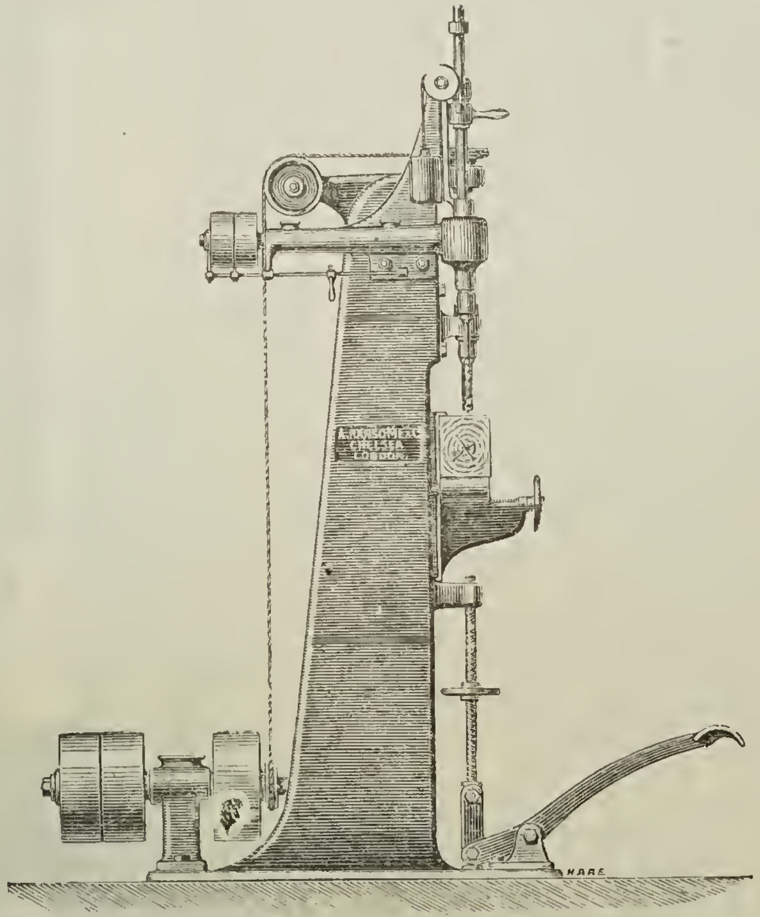


FIG. 154.



Richards's mortising-machine.

A silent feed is used here, as in several other similar tools exhibited by other makers. It is driven by a pin on a sector fitted to a main driving-crank.

The driving-gears of the feed are out of the way within the main frame. The rollers are weighted heavily, yet with conveniently-adjustable weights. The rate of feed is variable between 1 and 3 feet per minute.

The self-acting circular-saw bench (Fig. 156, page 281) is made with tables of from 5½ to 7½ feet length, and from 2¾ to 3½ feet width, requiring from 6 to 10 horse-power to drive them. The saws make from 800 to 1,000 revolutions per minute.

The feed-motion is driven by the saw-spindle, and is variable between 15 and 60 feet per minute. The feed-line is coiled on a drum, seen under the table, and, with all its gearing, is boxed in and preserved from injury by dust and dirt. The fence may be set at any angle, and may be nicely adjusted by a screw. It is taken off when not needed. The saw-spindle is of steel, running in three long bronze bearings.

The little molding-iron grinder (Figs. 157, 158) is intended to grind molding-irons of any pattern, without drawing their temper, and subsequently rehardening them. The spindle carries seven small grindstones of different thicknesses. These are turned up to fit the shape of the irons. Water is supplied through brass cocks, one of which is placed over each stone.

FIG. 157.

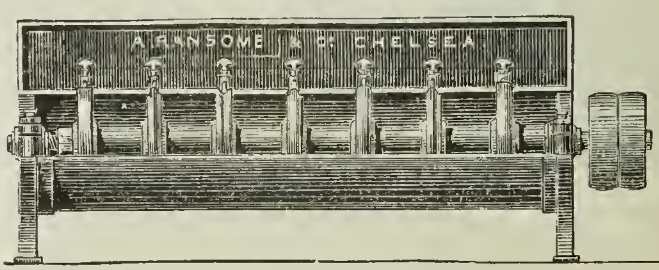
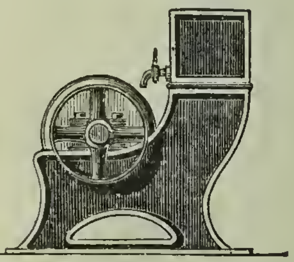


FIG. 158.



Molding-iron grinder.

On the panel-planing machine was an attachment which is deserving of especial mention. A suction-pan was applied to the conduit which conveyed the chips and dust from the machine, and the strong draught which it created drew in a current from all sides which effectually prevented any escape of such usually annoying particles. The workmen were thus enabled to do their work with accuracy and comfort, the dust was conveyed entirely away from the tool and expelled where it could do no harm and cause no annoyance, and the sanitary benefits of its use are, as the exhibitors claimed, no small inducement to its adoption. This apparatus, which the makers call their "pneumatic conductor," is shown in Figs. 159 and 160. It will be seen to be very similar to that adopted by the Tanite Emery-Wheel Company, of Stroudsburgh, Penn., for their Newman Emery-Wheel Planer.

271. Messrs. WORSSAM & Co., of Chelsea, exhibited a collection of wood-working machinery which was also most excellent in design, ma-

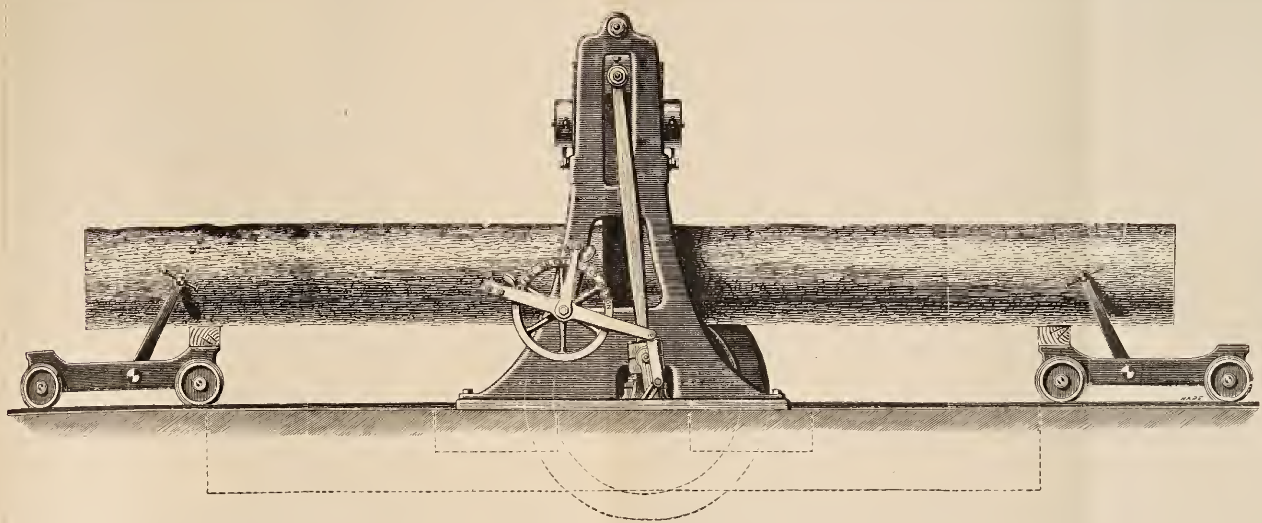


Fig. 155.—Ransome & Co.'s portable log-frame.

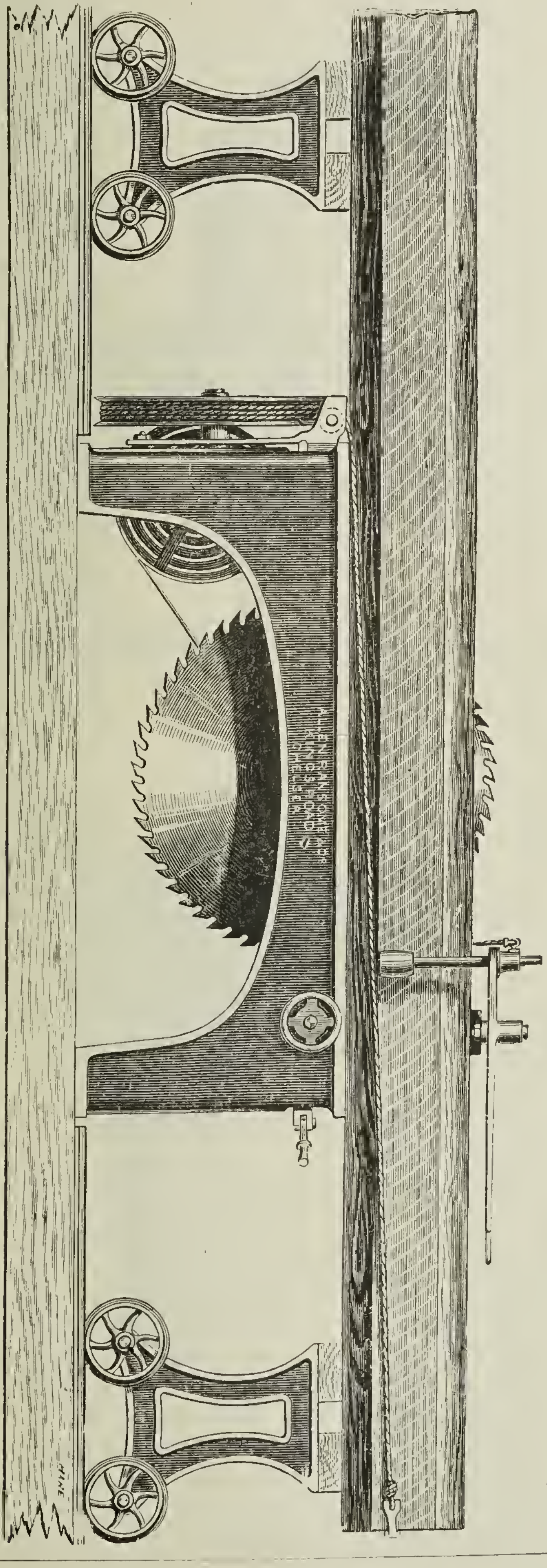


Fig. 156.—Ransome & Co.'s self-acting saw-bench.

FIG. 159.

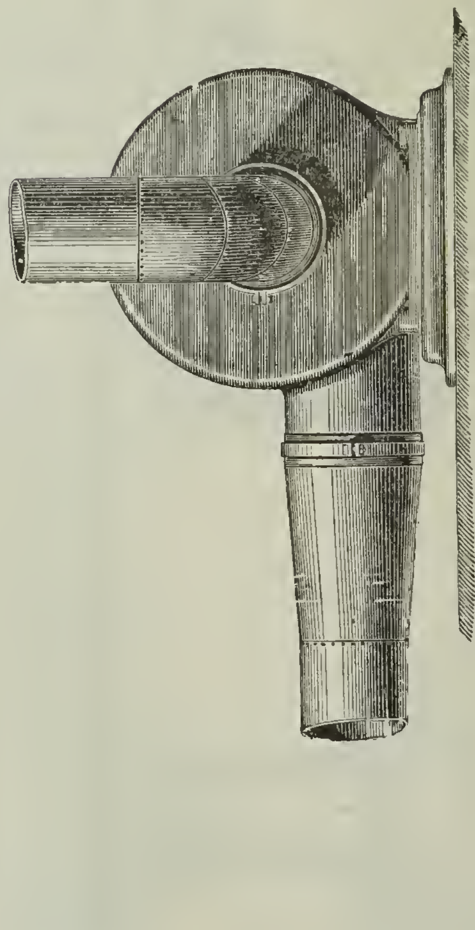
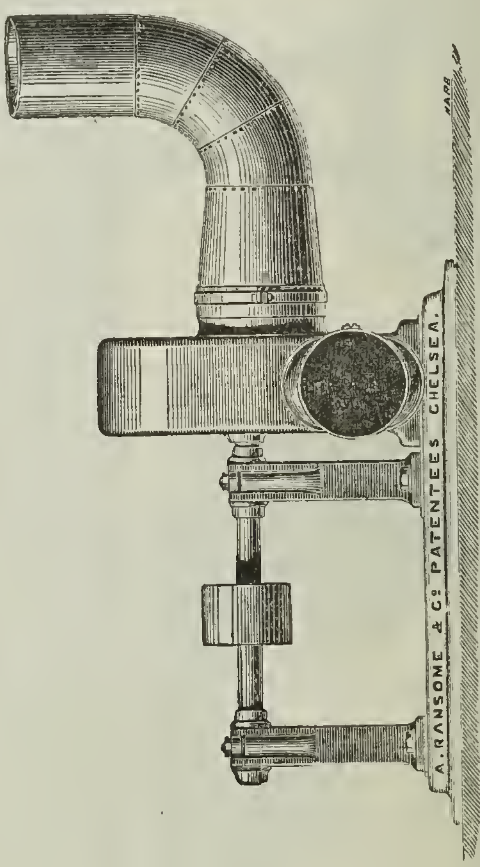


FIG. 160.



Ransome & Co's pneumatic conductor.

terial, and workmanship. They were rarely equalled, and in some respects they were in advance of their competitors.

Their parqueting-machines were good illustrations of their specially interesting work. One was a grooving and the other a surfacing machine. The latter was a face-plate lathe, having a strong, well-supported spindle, carrying a face-plate of good size. The tool was carried in a slide-rest which was well supported, and the whole design was as simple as could be desired, and as strong and stiff as is necessary in such work. The piece of work to be surfaced is secured to the face-plate, and the slide-rest carries the cutter in a line from the center outward, and *vice versa*, with perfect accuracy, leaving the surface well finished. In the first-mentioned machine, the block to be grooved is mounted on the table, with the edge to be cut extending beyond the table, which is then driven along its slides on the frame, and the work, coming in contact with the rotating cutter, is, at one motion, trued up and the groove cut. This little tool is also stiff and strong, neat and cheap, and does rapid work. The portable log-frame is a good machine also, resembling somewhat that already described.

Worssam's "general joiner" is a combination of tools intended for use where such a tool as that of Ransome & Co., already referred to, should be wanted. Here, however, the same shaft drives all the tools in the combination, an arrangement which necessitates starting all to drive one, and thus a serious wasteful consumption of power is inevitable, unless a vast amount of work is done upon this one tool, and in such well-distributed variety as to keep all parts of the combination employed. But, in the latter case, it would be far best to purchase independent tools, in order to insure freedom from interference of one piece of work with another, if for no other reason.

In this machine, tenons are cut by two small circular saws mounted at the proper distance from each other, and two other saws, set on a vertical axis, cut the shoulders. The work is fed vertically, and no inconvenience is experienced, except with unusually large pieces. The molding-machine in this combination is not as generally applicable as are some other machines, as it can only work one side, and that the top. The saw-table is well placed, and is fitted with a fence for ripping, and with a cross-cutting plate which can be worked handily, after turning the fence down.

A trying-up machine was exhibited in this collection, which seemed a good tool. It was used for surfacing, molding, and planing. It was intended especially for heavy work, but, by making a change of pressure-rolls, could be used on thin material.

272. Messrs. POWIS, JAMES & CO. exhibited a collection of wood-working tools which were excellent representatives of a standard, and, perhaps, somewhat conservative British practice. Like nearly all of the tools in this section, they were plain, neat, well made, substantial, good working tools. There were fewer peculiarities of detail than in the exhibits already described, but the makers were evidently among

the best, and deserved the position which they claim of leading makers of generally-used forms of wood-working tools.

Their saw-frame was solid and convenient, the planing and molding tools were well gotten up, and their whole department was well arranged and well cared for. Compared with the tools in the United States section, they illustrate well the peculiar differences of practice of the two nations.

273. THE FRENCH SECTION contained some excellent machinery. Without displaying the singular ingenuity of American manufacturers in adapting machinery to special purposes, and without exhibiting that solidity of design and that remarkable conscientiousness in doing good work which distinguishes the best British builders, the French, nevertheless, exhibited some fine work and some excellent machines.

Probably no nation has recently progressed more rapidly in this branch of industry than they. But a few years ago, this business was in the hands of a few unintelligent mechanics, and their work was of the worst possible description. To-day, the best of their machinists' work is seen in this department, and France stands only second to Great Britain and the United States. They do better work, and are far more original in design than their neighbors.

274. PERIN'S BAND-SAW.—The firms of Perin & Co. and of Arbey & Co. are especially deserving of notice.

The former is known throughout the world as the first to make a successful band-saw, and as having, for a long time, been the manufacturer of this now standard and invaluable tool.

The band-saws exhibited at Vienna (Figs. 162, 163) were of good design and execution, and would have called for especial commendation had they not been subjected to the disadvantage of a comparison with the beautiful American tools already described. They had no provision for taking up the extension produced by the rise of temperature consequent upon unintermitted working.

M. Perin informs the writer that he considers this provision, which is deemed so important by American manufacturers, useless, since, when a saw becomes warm enough to stretch sufficiently to slip on its pulleys, it is too warm to be used safely. The fact, however, that other builders go to considerable expense in adding this superfluous device, as M. Perin considers it, is probably very good evidence that it is decidedly advantageous.

M. Perin exhibited a variety of excellent blades. The manufacture of band-saw blades is claimed to be almost entirely a French industry. The finest band-saw blades in the Exhibition were those of Dougoujon ainé, 37 Rue de Lyon, Paris.

The steel used is sometimes English, often French, but the manufacture of the blades is carried on principally at Paris.

275. ARBEY'S PLANING-MACHINE.—The display made by Messrs. Arbey & Co. was excellent. The most noticeable exhibit was the planing-machine, (Fig. 163,) with helicoidal blades, which has already been mentioned.

BAND SAWS WITH ADJUSTABLE TABLE.

PERIN PANHARD & CIE

RUE DU FAUBG ST ANTOINE, 97, PARIS.

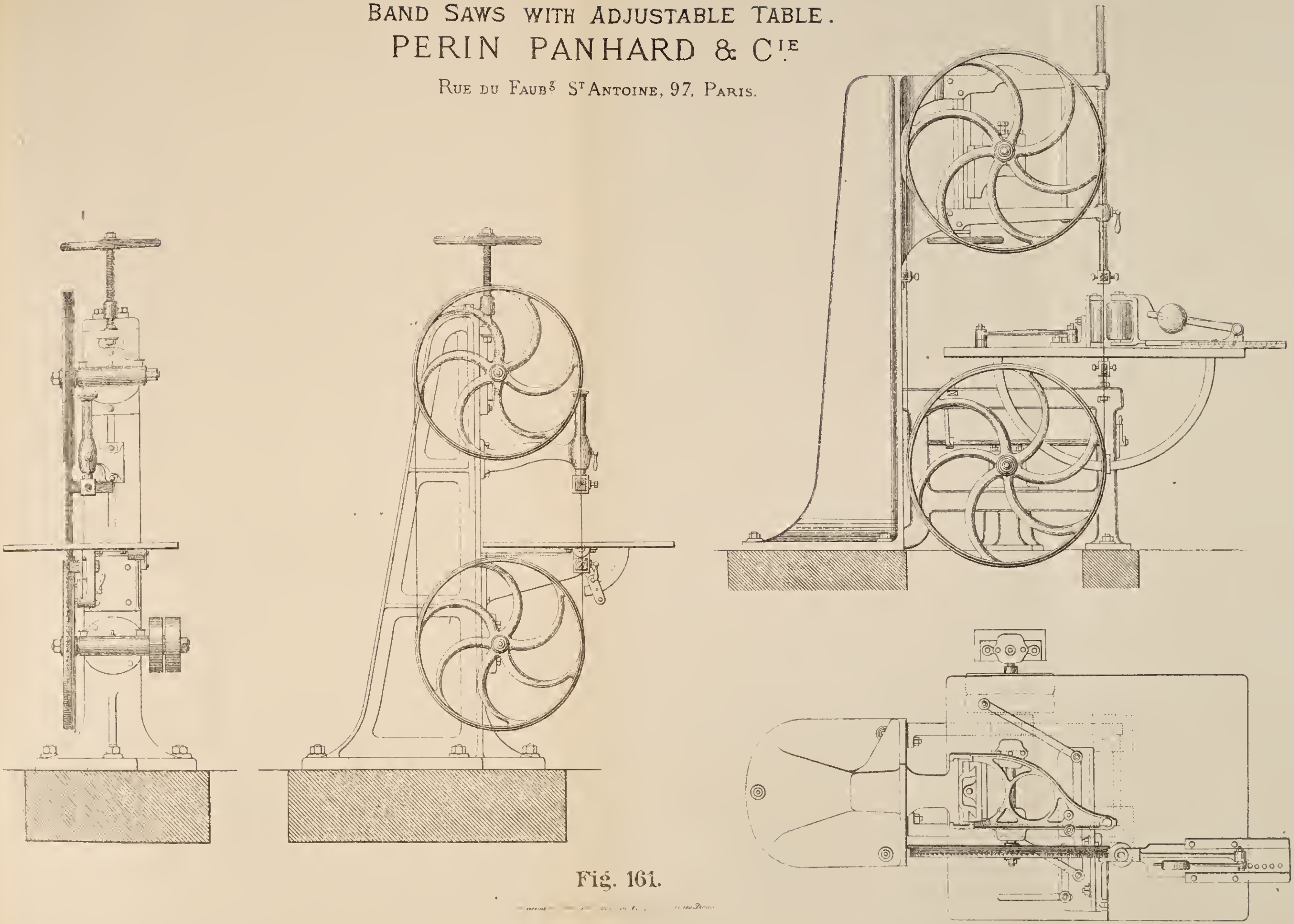


Fig. 161.

PAIR OF BAND SAWS MOUNTED ON SAME FRAME.

PERIN

Rue du Fg. St. Antoine, 97, Paris

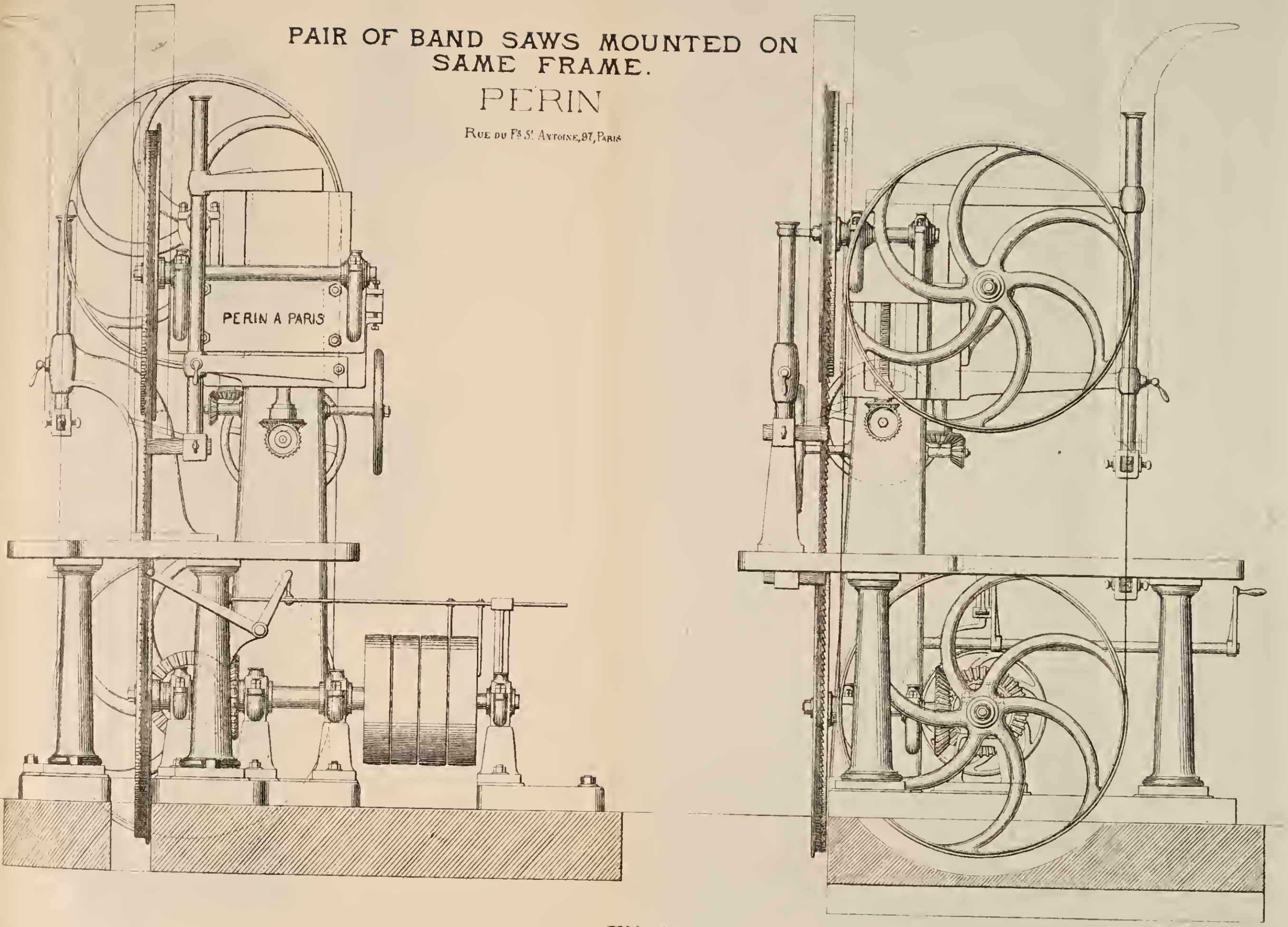


Fig. 162.

[illegible]

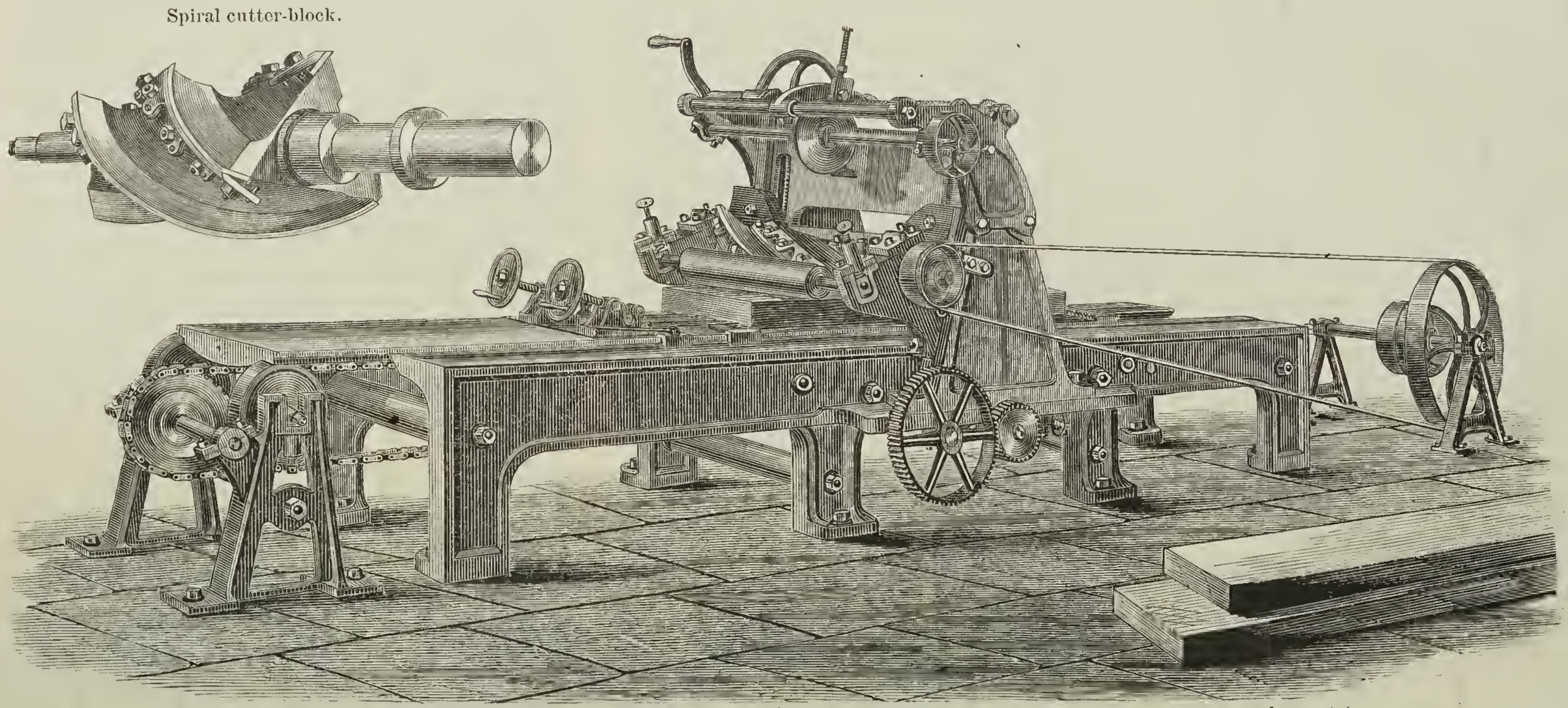

Spiral cutter-block.

Fig. 163.—Arbey & Co.'s planing and trying-up machine, (with spiral knives and sharpening attachment.)

The exhibitor claims for this machine that the form of the blades and the arrangement of the helices, which are placed in such a manner that before one edge ceases cutting the next commences, produce perfect regularity of motion and a uniform expenditure of power, presents the cutting-edges at every point in its path at the best angle for doing its work, and that the smoothness of the draw-cut thus made gives a surface which does not require the use of a finishing-tool.

The smoothness of motion secured enables the machine to do its work properly without being secured upon a massive foundation. The shavings are all thrown behind the machine, and do not annoy the attendant or clog the gearing.

The use of such thin blades as these, which are but one or two millimeters (.04 to .08 inch) in thickness, gives economy of first cost and but little trouble or expense for sharpening.

The really original device in the design, the principal feature being an American invention, was probably the use of a traversing emery-wheel, which sharpens the blades when in place, and without removal from the machine.

This seems to be a very important addition, and will probably insure the success of the machine. It enables the workman to sharpen the blades with great accuracy and rapidity, and makes it a matter of certainty that the surface of the wood will be left by the tool a perfect plane, and that, the machine being once in proper adjustment, the board will be left of precisely even thickness throughout.

Still another valuable feature of this planing-machine is that it may be supplied with a variety of cylinders and correspondingly-formed blades for various kinds of work. These "*porte-outils*" can be kept in a rack or a case by the machine, one or another being used as occasion requires. The expense of a considerable stock of the various kinds required for general use would be comparatively small.

These tools have been already largely used, and it is claimed that they work equally well on pieces of any size, straight-grained or cross-grained, with the expenditure of little power and without jar.

276. The accompanying illustration (Fig. 163) exhibits one of these Arbey planing-machines. Until within a few years these machines were always made with the old-fashioned straight knives. They are now mostly fitted with these Mareschal and Godeau's patent spiral cutters, which are claimed to be both theoretically and practically superior.

The fewer the number of fibers cut at once, in wood-working, the better and easier the operation. It is largely on this account that machines fitted with spiral knives are supposed to prove so efficient.

The principal features of these machines are as follows:

(1.) The pitch of the knives is such that the end of one comes opposite the beginning of the other. The result is that the knives are cutting during the whole revolution, the machine making about two thousand turns per minute. This does away with shocks on the bearings—the principal cause of heating. The knives always present the same angle to the wood, which is such as to allow cutting across the grain, even if knotty, and permits planing parquet flooring already put together.

As the knives are always cutting equally, vibration is entirely done away with* and wear and tear diminished; wood up to 26 inches width can be planed with a very slight increase of power. The shavings are all thrown to one side of the machine, instead of clogging up the working parts.

(2.) The knives used are very thin, from one to two millimeters, (.04 to .08 inch,) and quite flat; they are pressed closely to the spiral cutter-block by the back-iron and nut, and do not project more than 2 or 3 millimeters, (.08 to .12 inch.) They are very economical, not only on account of their cheapness, but of the short time required to sharpen them.

(3.) By a very simple arrangement they are sharpened in their places by the emery-wheel. The sharpening is perfectly accurate, as the wheel has only to be set and then allowed to run. As good work cannot be turned out without sharp knives, this improvement cannot be too highly estimated.

The machines with fixed tables are used for parquet flooring, moldings, and thin boards that do not require trying up.

Special machines are made for recessing railway-sleepers, for cask-making, and for cutting long tenons.

These planing-machines with spiral knives work wood, whether broad or narrow, thick or thin, along the grain or across it, without vibration and with very small power, and with great saving in sharpening and in wear and tear.

A large number of these machines have been supplied to the French government and to private firms.

M. Arbey exhibited a beautiful little fret-saw, and some equally creditable work done by it.

277. THE AUSTRIAN SECTION contained some excellent machinery, principally of designs which are everywhere standard. Austria in some portions is heavily timbered, and the manufacture of wood-working machinery promises to be an important industry. Pfaff & Co., of Vienna, had an exceptionally fine exhibit of saws.

The importance of securing the most efficient wood-working machinery, and at the same time the least expensive in first cost as well as in operation, in a timber-producing country like ours, it is impossible to overestimate, and our people may well be congratulated that our manufacturers are exhibiting so much intelligence and energy in meeting the wants of the country. It is not impossible, however, that they are doing their work too well, by facilitating the working of wood to such an extent that the destruction of our forests will, ere many years, produce evils so serious as to more than compensate those advantages which we are accustomed to consider of pre-eminent importance.

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* To such an extent that these machines can be put down on a common floor, as was done at the arsenals of Cherbourg and Brest.

CHAPTER XI.

TEXTILE AND MISCELLANEOUS MACHINERY.

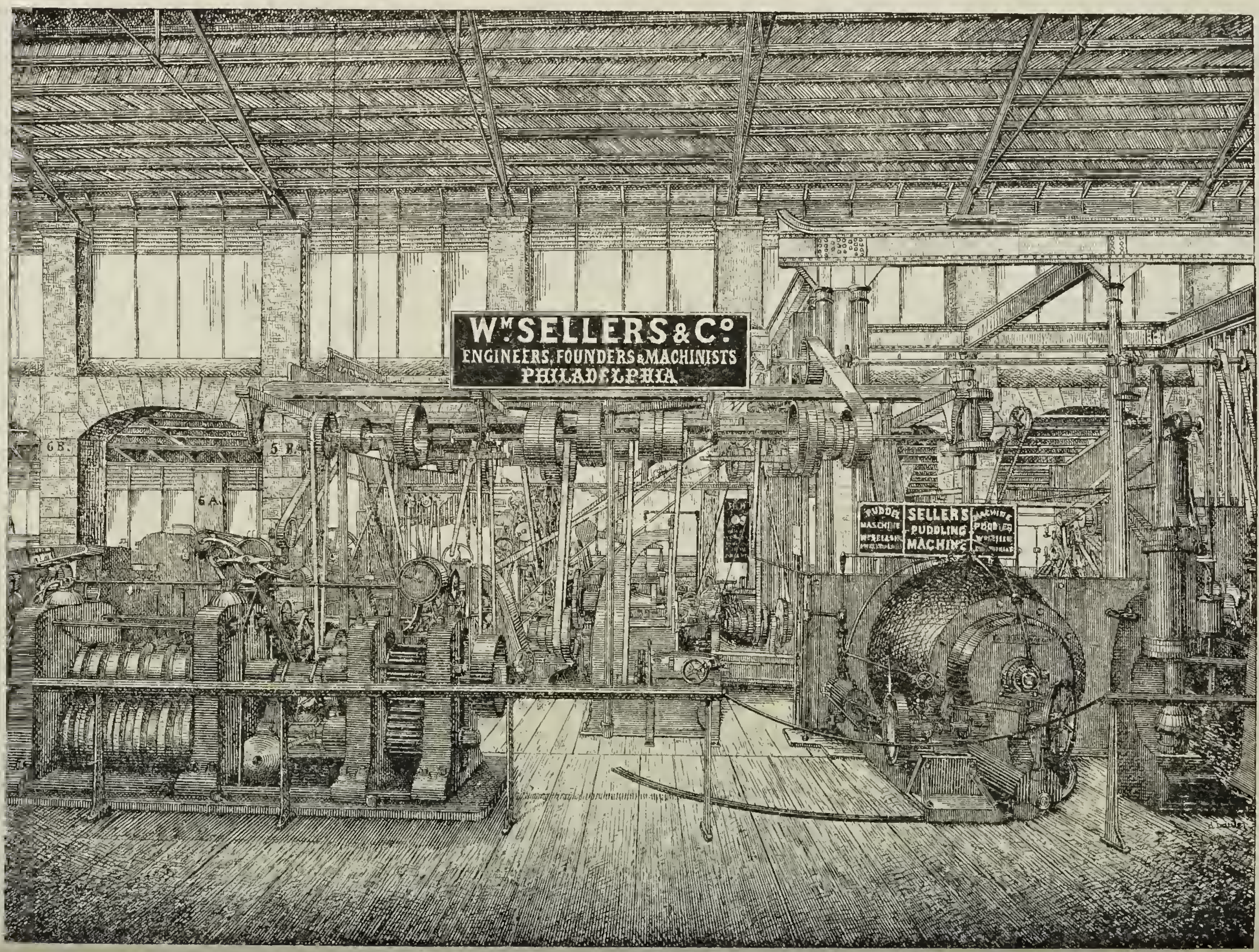
TEXTILE MACHINERY AT VIENNA; THE AVERY WOOL-SPINNER; ROSS' PICKER-MOTION; GENERAL CHARACTER OF EXHIBITS; SILK-MANUFACTURE IN SWITZERLAND; SEWING-MACHINES—ATTACHMENTS, AND METHODS OF MANUFACTURE; THE SELLERS ROTARY PUDDLER; THE SELLERS STEAM-HAMMER; B. & S. MASSEY'S STEAM-HAMMER; THE WOODBURY BRUSH-MACHINE; STEPHENS' PARALLEL VISE; BIGELOW'S SHOE-MACHINERY; THE BILLINGS & SPENCER CO.'S DROP-FORGINGS; TILGHMAN'S SAND-BLAST; WEST'S TIRE-SETTER; MILLER'S PIPE-BENDING MACHINE; WARTH'S CLOTH-CUTTER; DARLING, BROWNE & SHARPE'S MEASURING-APPARATUS; THE MORSE TWIST-DRILL COMPANY; THE SCOTT GEAR-MOLDING MACHINE; JONES & LOUGHLIN'S COLD-ROLLED SHAFTING—METHODS OF ITS MANUFACTURE; COLD-ROLLED BRONZE OF S. B. DEAN AND OF GENERAL UCHATIUS; CHARACTER OF ORDINARY BRONZE; BRONZE CAST IN CHILLS; UCHATIUS'S THEORY; ALLOYS BEST ADAPTED FOR CASTING IN CHILLS; BEST METHODS OF WORKING BRONZE—UCHATIUS'S METHOD—USE IN ORDNANCE—TESTS—EFFECT OF STRETCHING BEYOND THE ELASTIC LIMIT; OTHER APPLICATIONS OF COLD-ROLLING; COMPARISON OF STEEL WITH COLD-ROLLED BRONZE; UNDERHILL'S ANGULAR BELT; HYDRAULIC FORGING; FORGED LOCOMOTIVE WHEELS; APPLEBY & BRO.'S AND J. H. WILSON & CO.'S STEAM-CRANES; HORTON'S LATHE-CHUCKS; GERMAN OPINION OF AMERICAN TOOLS.

278. A considerable display of the machinery of textile industry was exhibited at Vienna, but it was not rich in novelties.

Of wool-working machinery there was far less exhibited than of cotton-machinery. The machines were of well-known standard forms, and only attracted attention by fineness of workmanship or the neatness of finish. A considerable number were in operation, particularly in the British and in the Belgian sections, and, as a rule, their performance was all that could be asked. Platt Bros., of Oldham, England, and Bede & Co., of Verviers, were the prominent exhibitors. The former exhibited the only wool-comber noticed by the writer. The wool-comber of the late Cullen Whipple, of Providence, R. I., an American invention recently introduced into the British market, was not shown, although probably a much better machine for all lengths of staple.

279. THE AVERY WOOL-SPINNER.—A machine in the United States section attracted more attention, and seemed generally considered to be of more promise than any other wool-working machine exhibited. This was the "Avery continuous wool-spinner," an invention of Mr. Luther W. Felt.

"This machine," says Dr. Grothe, "excited great admiration among woolen manufacturers, on account of its seeming to accomplish in a very small space, and with great economy of construction, a better pur-


Wm. SELLERS & Co.
ENGINEERS, FOUNDERS & MACHINISTS
PHILADELPHIA
6B.
5B.
6A.
MASCHINE
SELLERS
PUDDLING
MACHINE

pose than machines of ordinary types. Avery's spinning-machine for corded yarn is more similar to the original spinning-machine of Hargreaves than any other construction so far introduced. It appears that in this sense Avery's invention shows a retrocession, but in reality it must be acknowledged that it is a progress. Avery's invention is not only an important contribution toward the long-sought solution of the problem of effecting the continuous spinning of corded yarns, but it also utilizes parts of former machines which are themselves of value. We know that four or five years ago the too-willingly rejected simple arrangements of Hargreaves' machine had to be again adopted; that, indeed, nearly the whole of this machine was reproduced, but with the difference that the nipping-apparatus is fixed and the spindles movable. However, these experiments gave satisfactory results only for ordinary wool. Avery must have carefully observed Hargreaves' nipping-apparatus, and it is evident that he decided to remove the objections to which it is open."

This machine was exhibited at the Annual Exhibition of the American Institute at New York in 1871, and was there given a high award, the justice of which was fully confirmed by that given at Vienna in 1873. The wool-spinner exhibited was a small machine of rather rough design, but of good workmanship, and was proven to be capable of doing excellent work, even on wool containing a considerable proportion of shoddy. The roving is fed from the spool by a revolving drum driven from the pulley-shaft, and is delivered to peculiarly-constructed wheels, which seize it at the proper moment and release it again as the spinning occurs, and the required draught is thus given. The drum and the cage-wheel with which it acts revolve at the same speed. The roving, as delivered, hangs down loosely until sufficiently twisted, when the next motion delivers a new supply and takes up that already twisted.

280. The action of the machine is quite a simple, but a very ingenious, combination of movements. It cannot, however, be fully described without elaborate drawings. It is one of the most important and promising of recent inventions in this department. A machine in the Belgian section was intended to accomplish the same object, but it was of quite different construction, and seemed far less effective.

The Avery spinner was simple in construction, quite well made, and did good work. The wool was of short staple, and from it a yarn was made, very fine and even, and comparing well with yarn made by the best machines of ordinary construction. A large percentage of shoddy can be worked in. The machine was stated to be capable of doing its work better and quicker, at one-half the expense, and to occupy one-fourth the space of the best of other machines. It was stated by experts to make very little waste, and to require comparatively little power. The machine was one of the most perfectly original inventions exhibited.

281. Messrs. Bede & Co. and C. Martine, of Verviers, each presented a fine collection of wool-machinery, and among them were some observ-

able improvements in matters of detail which were considered by many visitors to be unusually creditable. The British machinery of Platt Bros. was unexcelled by anything at Vienna, and many American manufacturers think it superior to that built in this country by our best makers. The fact that our own manufacturers of such machinery are gaining in competition with their British rivals would, if correctly stated, however, indicate the contrary.

Austrian and German builders exhibited some excellent machinery of this class, and the Swiss makers were at least fully their equals.

282. The greatest variety of textile machinery was found among the looms.

Mr. LESTER E. ROSS, of Providence, R. I., exhibited his independent picker-motion on a loom driven by Allen's friction-clutch pulley, and both devices attracted much attention. The workmanship of the apparatus was exceedingly creditable to the manufacturers—the Star Tool Company, of Providence, R. I.—and the loom, at 250 picks per minute, does excellent work. The peculiar feature of this loom was the mechanism by which the shuttle carrying the woof was propelled.

The earlier method of accomplishing this was by a cam or lug attached to and revolving with the shaft of the loom, and which gave a sudden blow, the force of which depended upon the speed of the loom. The speed of the loom being momentarily increased or diminished, from whatever cause, the shuttle would be thrown with greater or less force, as the case might be, and, consequently, no uniform motion of the shuttle could be obtained without absolute uniformity of speed. By means of this improvement, however, perfect uniformity of motion is given the shuttle, as it is propelled by a force independent of the speed of the loom, and it is hence called an "independent shuttle-motion." The shuttle is driven by a series of springs coiled upon a shaft. After each motion of the shuttle from side to side, the springs are strained up by means of a cam, and the power is "let off," at the proper time, by the same cam.

It is claimed for this new motion:

(1.) That looms to which it is applied can be run at any speed, from one pick to two hundred and fifty picks per minute, or at any possible speed required.

(2.) That variations in the speed of the loom, however great or sudden, will not affect the operation of the shuttle, and that such variations will require no re-adjustment of straps, boxes, or any other part of the loom.

(3.) That a better fabric must be produced, since the tension of the filling is not affected by the speed of the loom, and no jar is made on the lay-beam by the pick.

(4.) That less waste is made, since the force of the shuttle is not varied by the motion of the loom, and the cop, therefore, is not liable to be broken.

(5.) That the cost of the motion is less than that of any other shuttle-motion in use.

(6.) That the expense of operating the loom will be greatly lessened, since the shuttle-motion is more durable, there being no point liable to wear, no breaking of picker sticks or straps, no sudden shock, as by the blow of the cam in other motions, and less liability to "shuttle-smashes," because there is no danger of the shuttle's bounding back, or failing to "box," from variations in the speed of the loom, and since the cost and delays incident to repairs are consequently greatly reduced.

(7.) That less power is needed, and less time, attention, and skill on the part of the operator required to run the loom.

(8.) That it is adapted to all kinds of looms, and may be easily applied to old looms without alteration.

283. PLATT BROTHERS exhibited in the British section a cotton-gin designed especially for the woolly seed of upland cotton. It did excellent work, cleaning the seed well, and without breaking up the fiber seriously. The general form resembled somewhat a gin exhibited recently at the American Institute Exhibition, and the use of weights instead of springs to force the rollers against the knife was claimed to insure good work, even in unskilled hands, securing a uniformly-applied pressure and certainty of action. The gin was stated to be able to work off 120 pounds per hour of clean cotton from upland seed, and 200 pounds from sea-island cotton-seed.

The exhibit of textile machinery was, as a whole, far more remarkable for its magnitude than for novelty. In the exhibit of Bede & Company, the use of friction-gearing was an innovation which, if as successful as it is claimed to be, will be largely imitated.

The exhibition at Vienna of one of our best card-setting machines, of our harness-making machines, of some of our well-known inventions, and standard machinery in this department, would have added immensely to the interest of the United States section of the exhibition contained in the machinery-hall.

284. THE SILK-MANUFACTURE is with us a comparatively youthful branch of industry, although a few manufacturers have, in isolated cases, been long engaged in it. Naturally it had no representation in the United States section. France and Switzerland had very interesting exhibits of silk-working machinery, and it was easy to trace the whole process of silk-manufacture, from the winding of the fiber from the cocoon to its final appearance in the woven goods.

The process of spinning was remarkably well and largely illustrated in the Swiss section. It is quite different from cotton or wool spinning, and consists merely in twisting together the requisite number of fibers to produce the desired size of thread. The "drawing," which is so important a part of the process of spinning textile materials of short fiber, is not necessary or possible here. Among the silk-looms were several very fine specimens, which were at work weaving silks of various widths and patterns.

Switzerland exhibits some examples of waste-silk-working machinery. As the fiber is, in this case, much broken up, and resembles more nearly those more familiar textiles, cotton and wool, the process of working is intermediate between that by which new silk is worked and the ordinary method of working long wools.

If we may judge by what was shown at Vienna and by the statistics given in Part II, the silk-manufacture of Switzerland must be a large and an exceedingly important branch of that nation's industry.

285. SEWING-MACHINES can hardly be classified with the textile machinery, but they are hardly second to them in importance, and they appeared in every section of the machinery-hall in wonderful variety and in great numbers. The more important were of American make, or were copies, made with great accuracy frequently, of American machines. The manufacturers of Great Britain and of the continent have imitated our methods of manufacturing, and often produce exceedingly creditable work. The exhibit of sewing-machines in the United States section was very extensive, and all of our standard machines were well represented. This was one of the most attractive departments of the whole *Welt-Ausstellung*, and interested all classes of visitors. Examining carefully the construction of these machines, and comparing those of foreign make, it is soon discovered that where defects occur in the latter they are generally the result of a lack of knowledge of the proper distribution of material. The machines were made of standard forms, and their parts were always made to gauge and were interchangeable; but still the fits were sometimes a little loose, and the neat adaptation of the special qualities of steel and of iron, or of case-hardened iron, which invariably distinguishes the American productions, were sometimes not seen in the foreign copies.

286. The large number of ingenious and convenient attachments which accompany the American machines is also one of their distinguishing characteristics. The foreign manufacturers do not invent them, and they are somewhat slow in adopting those invented in the United States. It is not at all remarkable that, notwithstanding the fact that so many sewing machines are now built in Europe, many thousands are still annually exported from America. Even the humble cottagers of Bohemia and the semi-civilized people of Russia and of Turkey are now becoming purchasers of these universally-useful little "labor-savers." A resident of Sweden states that the poor peasants of that country also are succeeding, frequently, in satisfying the ambition, which is common to all, of possessing an American sewing-machine. The sewing-machine has thus become one of the most important aids in the advancement of civilization. Increase of production and the decrease of prices are matters of great moral as well as commercial importance. The expiration of the last of the important patents upon essential details will soon take place, and these very desirable consequences must soon follow.

287. VARIOUS UNCLASSIFIED EXHIBITS. — Besides the machinery

noticed in the preceding sections of this report, there were many exhibits which deserve more than a passing mention.

In the exhibits of Messrs. Sellers & Co. were included a Morrison steam-hammer, embodying improvements devised by the builders, a novel revolving puddling-furnace, and a 12-inch rolling-mill train.

The latter was simple in construction, well proportioned, and well built. Its neatness and its substantial appearance secured for it much commendation.

The SELLERS ROTARY PUDDLER was a most interesting and ingen, ious machine. The heat was intended to be supplied by a gas-furnace- the flame being directed into the puddling-furnace at the upper portion, and after eddying downward within the egg shaped vessel, passed out at the end at which it had entered, through an opening below that which afforded ingress.

The puddling-furnace was therefore open only at one end. This construction secures greater strength in the shell, a more eliable adhesion of the lining, and some important advantages of manipulation.

The furnace was supported by " friction-wheels " at one end and on a horizontal pivot at the other. The power required to produce its rotary motion was comparatively small.

A small horizontal steam-engine was mounted by the side of the furnace, on the same supporting-frame. The whole apparatus was carried by this frame, which was pivoted at the end nearest the open end of the furnace, the pivot-bolt being placed a little on one side and beneath the furnace-mouth.

The engine was so attached that it could be used either to revolve the furnace or to swing the whole machine about the pivot-bolt. A neat little device permitted reversing promptly, and every change could be made with great facility. The material and workmanship, as well as the general design, fully sustained the reputation of the makers.

In operating this furnace, a man stands upon a little platform on the main frame by the side of the engine, and, after first allowing the furnace to become well heated up, he sets the engine in motion and swings it into a position at right angles to the face of the flue-wall.

The pig-iron is then charged. Messrs. Sellers & Co., instead of charging solid metal, as is customary elsewhere, melt the pig-iron in a cupola-furnace, and run molten iron into the puddling-furnace, thus shortening and cheapening the process, and saving the furnace-lining from the serious abrasion consequent upon careless charging with solid pig-metal.

The furnace is then run back into position and set in revolution ; the gas-flame having been given an oxidizing character, the process of decarbonization goes on until the iron balls up, as in the Danks and other " rotary " puddling-furnaces.

The ball of sponge is removed by first turning the furnace away, as when charging, and handling the balls with properly-arranged apparatus.

The details of the method of working and handling the metal, as practiced at the Messrs. Sellers's iron-works at Edgemoor, near Wilmington, Del., are exceedingly ingeniously planned, but a description would be out of place here.

288. In SELLERS' MORRISON STEAM-HAMMER (Fig. 165) the weight is principally in the piston-rod, which is made very large both above and below the piston, but largest below. The piston is welded to the rod. The heads of the steam-cylinders form the guides, preventing the lateral movement of the hammer, and one side of the upper portion of the rod is planed flat to prevent turning.

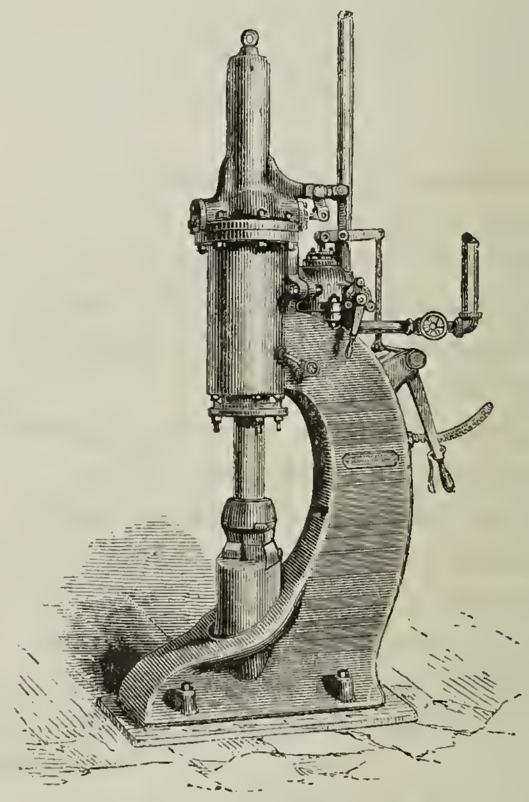


FIG. 165.—Sellers's "Morrison" steam-hammer.

The hammer-head is secured to the rod by a circular key, a ring of wedge-shaped cross-section, but which is readily loosened by removing the top die and striking a light blow on the anvil-block.

The valve-movement is automatic, or a hand-motion is used, as desired. In the former case, the motion is obtained by two opposite grooves of varying depth cut into the rod, in which grooves a yoke is fitted, which, bearing on the inclined surfaces forming the bottoms of the grooves, is given a motion which is transmitted to the valve. The line of motion passing through the center-line of the rod, there is no tendency to twist the latter.

The valve is balanced. A supplementary valve permits choking the exhaust where quick, light blows are wanted, as in finishing work.

The tool is admirable in every respect. Sellers & Co. also exhibited their latest style of Giffard injector for feeding boilers. This wonderfully beautiful and ingenious yet simple device owes much of its present effectiveness to this firm, who are the licensees in the United States. The self-adjusting device by which the apparatus adjusts its own water-supply is hardly less important and beautiful than the main inventions.

Mr. CHAS. CHURCHILL, of New York, exhibited a considerable variety of metal-products, including the standard metal-workers' tools. One of the most novel was the STEPHENS' PARALLEL TOGGLE-JOINT VISE.

This neat and ingenious device is constructed in a considerable variety of forms by the Colt Armory Company, of Hartford, Conn. It is illustrated in the accompanying sketches. Fig. 166 represents the tool as usually mounted on the work-bench. on a swivel, and capable of taking any desired position for convenience in working upon the piece held in its jaws. As shown, the jaws are closed upon the work and the handle thrown up against the side of the slide.

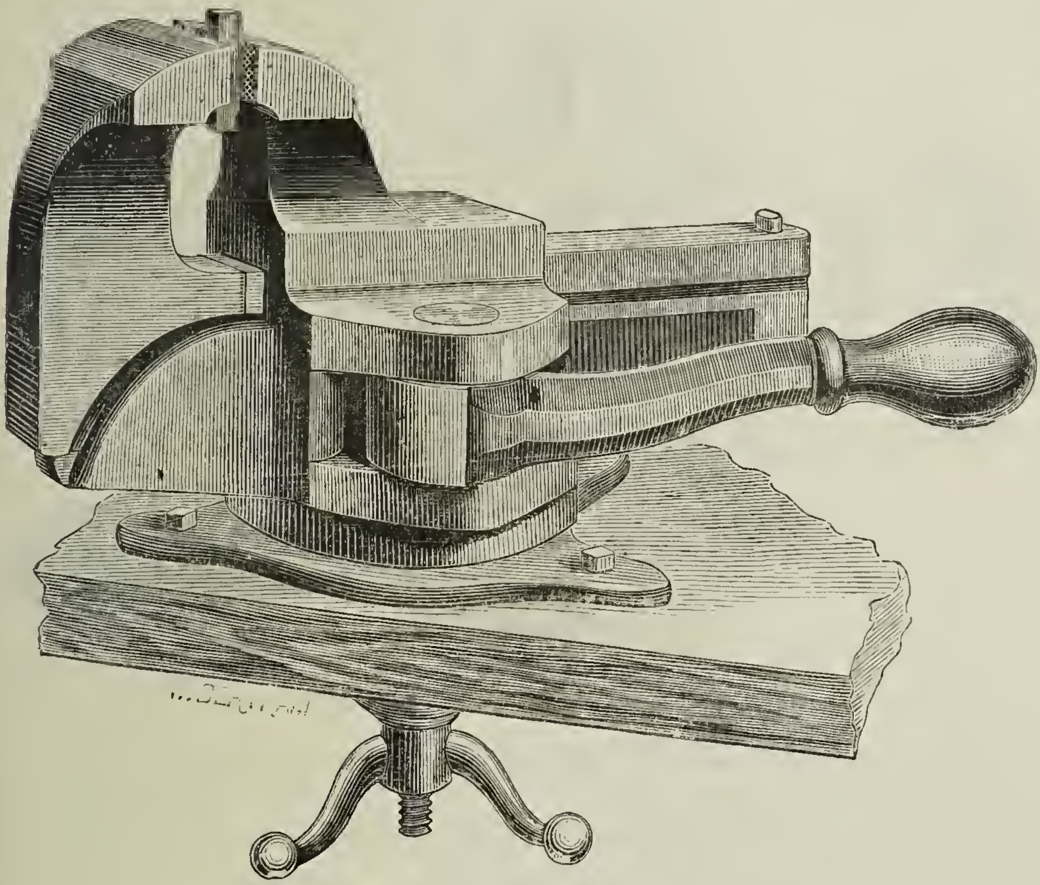


FIG. 166.—Stephens' parallel vise.

Fig. 167 is a plan in part section, showing the mechanism by which the handle clamps the piece in position. The toggle $G\ G^1$, the tooth-bar *t*, the spring S, the cam C and handle H, carrying a hook, M, are the peculiar and essential parts of the device. The sliding-bar B B is provided with a steel rack, T, and engages the tooth-bar *t* when the vise is in use.

The work being placed in the vise and the jaws brought up into position to clamp it, the handle H is thrown outward, the hook M slips off the projection *m*, and the spring S, acting upon the point U, forces the tooth-bar *t* into contact with the rack T. Continuing the outward motion of the handle, the cam C comes in contact with the projection *n*, straightening the knee-joint, and, by driving the sliding-bar backward, forces the movable jaw firmly against the work, holding it in place with great force. The vise is very quick in action, handy, strong, and very powerful in its grip. It has very little friction, and would seem likely to prove durable. The work is released easily by the slightest reverse motion of the handle. The manufacturers have a remarkably large variety of attachments and of modified forms of this vise, fitted for the peculiar demands of the several trades.

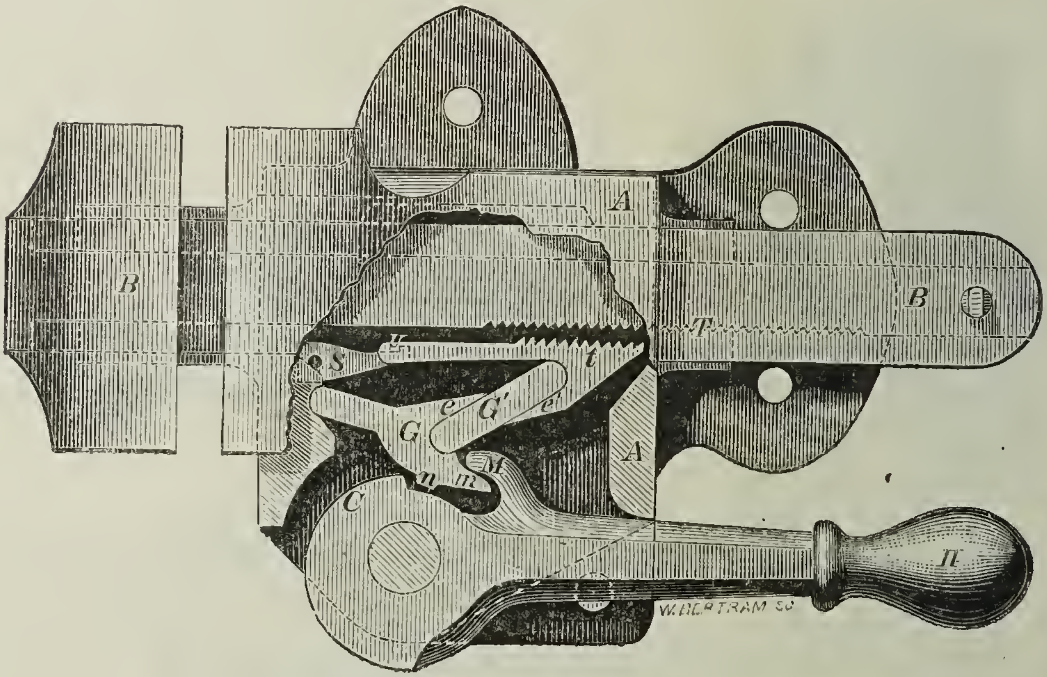


FIG. 167.—Stephens's parallel vise.

The swivel on which the vise is mounted, as shown above, (Fig. 166,) is a very elegant and simple device. It consists of a plate which may be bolted or clamped upon the bench or on a table, and carrying on its upper face a ring of wedge-shaped section. A similar ring is cast on the upper part of the swivel, which fits into the first-named ring. A bolt passes through both, and its nut is turned by means of projecting arms. On setting it up, the two rings are clamped together, and, the inclined surfaces coming snugly against each other, the vise is held firmly, and can neither turn nor shake.

The exhibitor, in his circulars, gives a comparison of the relative extent of rubbing-surface in this and in the common screw-vise, making them as one to nearly nine hundred, and estimates the required time of opening and closing to be as one to fifty. The taper attachment for holding tapers is one of the many neat and handy attachments which are supplied with these vises. Fig. 168 exhibits its construction better than can any verbal description.

The BILLINGS & SPENCER MANUFACTURING COMPANY, of Hartford, Conn., exhibited a great variety of parts of machinery, solid forgings for sewing-machines, guns, and small tools. They were all made in drop-presses—a class of tools described when referring to the exhibit of Messrs. Stiles & Parker. These were very fine specimens of this kind of work, and many of them were master-pieces of accurate forms and intricate shapes. This firm have made a specialty of this kind of work and have succeeded in producing some pieces of work which could only have been made by a very skillful workman, if it could have been done at all by hand. The heavy blow of the drop-press, forcing the metal, at a single stroke, into the die, does its work so quickly that the metal has no time to cool, and therefore so thoroughly that no defects of internal structure can be produced or can remain if originally present. It does its work so accurately that every piece is the precise counterpart of every other piece made in the same dies, and each is precisely of the size and form demanded. It does its work so rapidly and cheaply that, where the number of pieces to be made is sufficient to justify the making of the dies, there is no comparison in economy between this and the ordinary method of hand-forging.

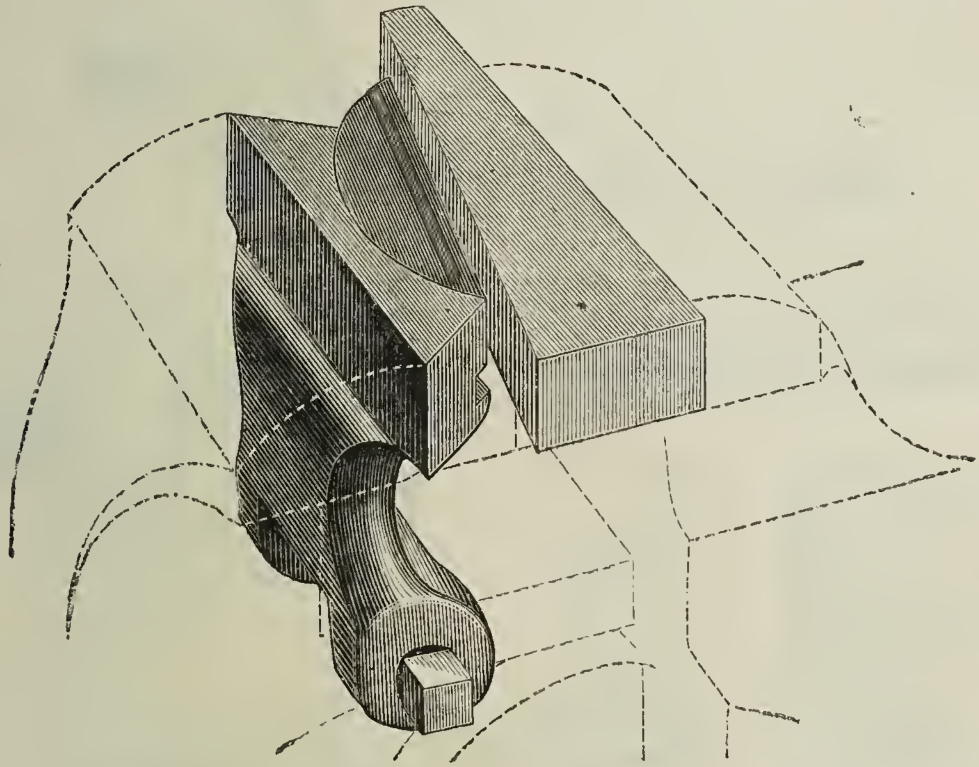


FIG. 168.—Taper attachment for irregular work.

The use of the drop-press was first introduced into general use among the jewelers, and among manufacturers of the light, thin cases used for daguerreotypes, and makers of similar products. The tool was next applied to special operations in gun-making, and in making bolts, nuts, and small rivets. It has now become so generally used that tool-builders find a considerable market for the styles of this machine which each makes in some variety. Several firms are making a regular and an extensive business in supplying drop-forgings to sewing-machine companies, makers of fire-arms, and other manufacturers who make exten-

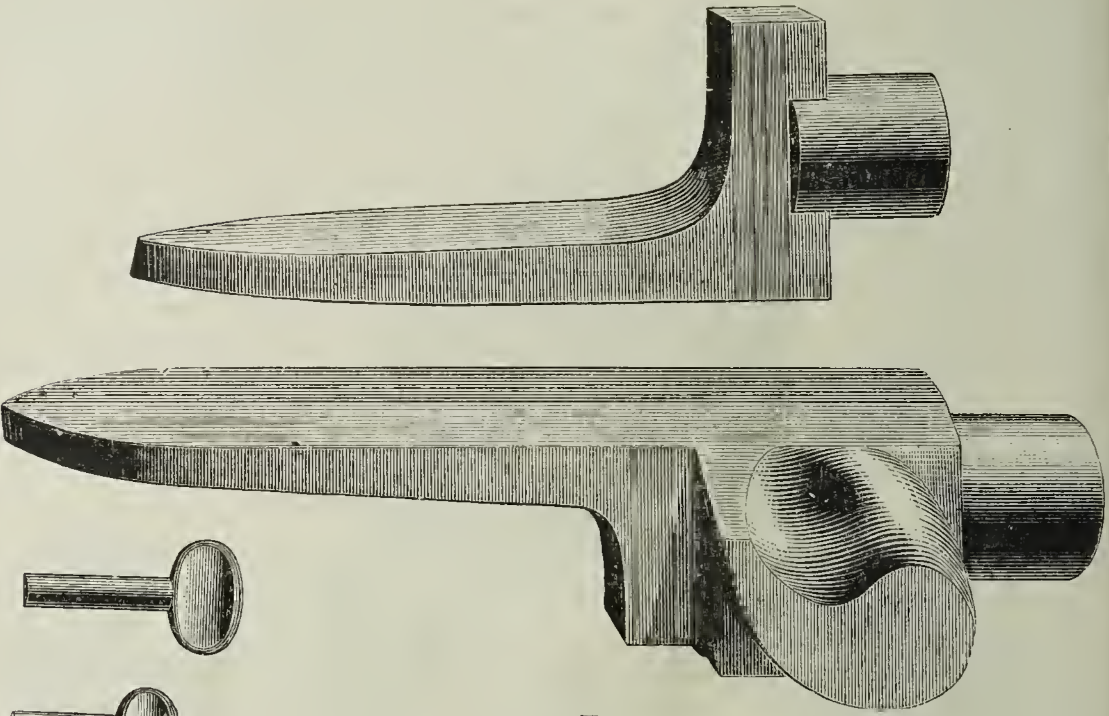


FIG. 169.—Rifle-breech pins.

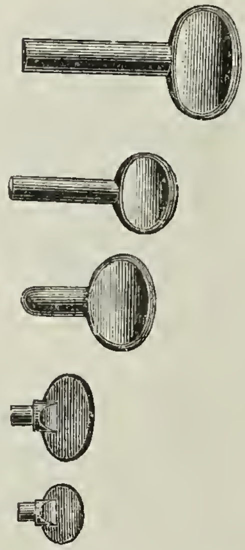


FIG. 170.—Thumb-screws.

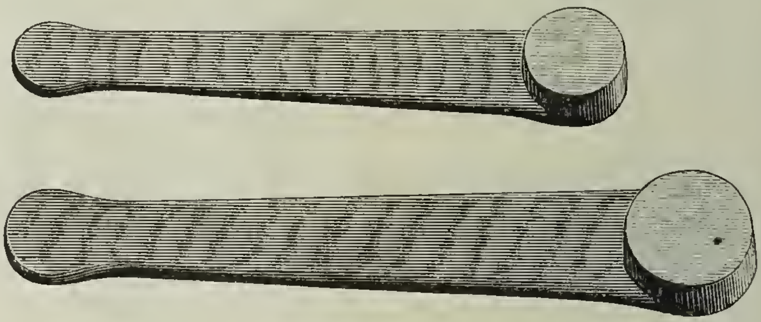


FIG. 171.—Milling-machine cranks.

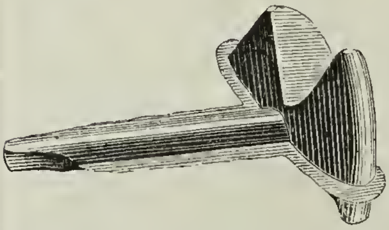


FIG. 175.—Wilcox & Gibbs sewing-machine hooks.

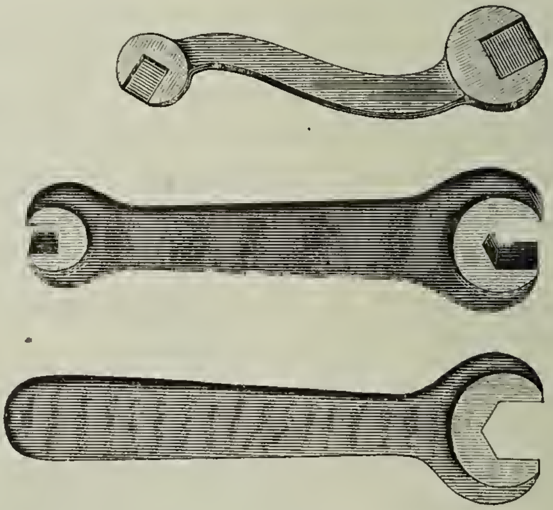


FIG. 172.—Machine-wrenches.

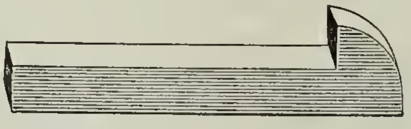


FIG. 176.—Key.

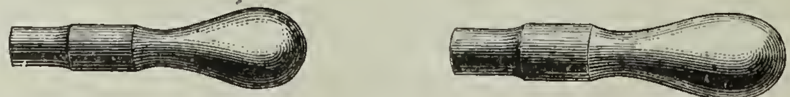


FIG. 173.—Machine-handles.

sive use of small iron and steel parts in their work, in great numbers and of precisely similar form and size. The Billings & Spencer Company are well known in the United States as among the largest and most successful makers of drop-forgings, and nothing shown in other sections of the Exhibition, or, indeed, in the manufacturing establishments of Europe, so far as the observation of the writer has enabled a judgment to be formed, equals their work. In fact, the business does not seem to have taken definite form there as it has in our country; but it is not probable that, thoroughly awakened as European manufacturers have, of late years, become to the importance of the peculiar modifications of practice which have come to distinguish the industries of the United States in so marked a manner, that this modification of practice in forging will remain long peculiar to the United States.

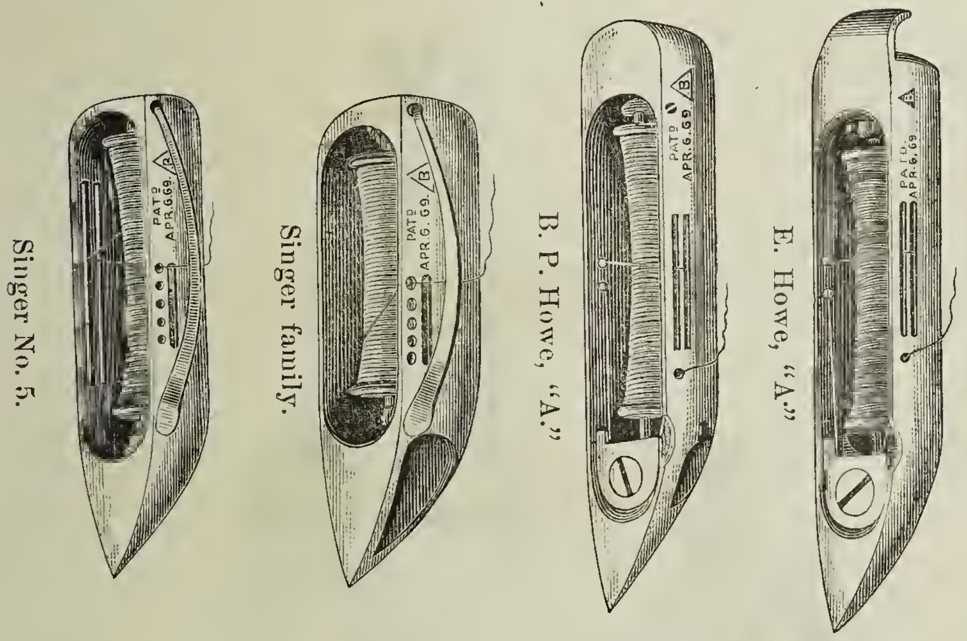

Singer No. 5.
Singer family.
B. P. Howe, "A."
E. Howe, "A."
PAT'D APR.6.69.

FIG. 174.—Sewing-machine shuttles.

Figs. 169 to 176 exhibit some of these interesting specimens and the most important and most difficult forms. The rifle-breech-pins (Fig. 169) and the shuttles (Fig. 174) are remarkably fine examples of this kind of work. This firm either furnish these pieces in the rough or finished.

289. Messrs. B. & S. Massey exhibited several fine steam-hammers in the British section. They state that their small hammers are specially designed for smiths' work of every kind, and are applicable for the lightest descriptions of forgings, such as have usually been made by hand.

In consequence of the almost endless variety of purposes to which they are adapted, steam-hammers are economical even in the smallest smiths' shops, and even with only a single fire. Some of their principal advantages are:

A great saving in wages, as one smith with a steam-hammer can do as much as two or three without it, and for the smaller sizes he will not need an assistant.

Great economy in fuel, as, at one heating of the iron, so much more work can be done than is possible by hand.

Economy of iron, since scrap-metal, which is commonly almost useless, can be worked up into forgings of good quality.

The forgings may be so accurately finished as to require little labor in fitting and turning. In many cases the saving is said to amount to 50 per cent., or even more, defraying the cost of the hammer in a few months.

All of the hammers of Messrs. B. & S. Massey are double-acting, and will strike lightly or heavily, quickly or slowly, long or short strokes, and elastic or dead blows, as desired. Large hammers are usually made by them to work by hand only; but the smaller ones are ordinarily arranged so as to work both self-acting and by hand. They work without jar or shock.

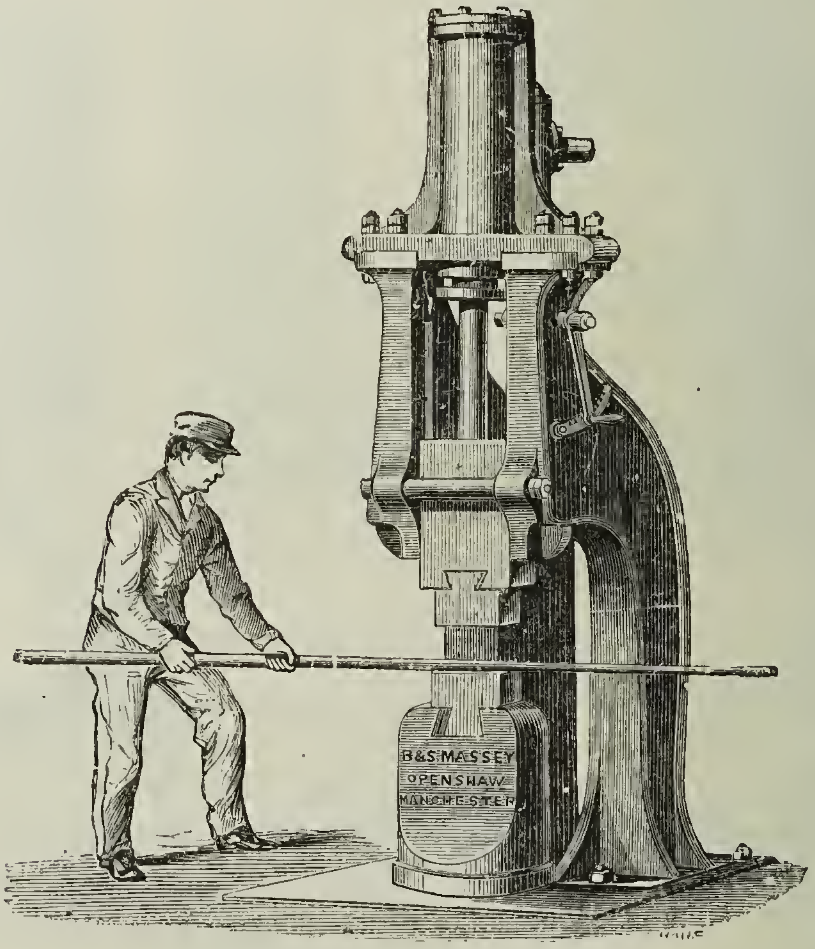


Fig. 177.—Massey's 5-cwt. steam-hammer.

Their 5-cwt. steam-hammer, for general smith-work, (Fig. 177,) is specially designed for the use of smiths, whether for machine-making, engineering, gun-making, ship-work, railway-work, agricultural-implement work, or any other class for which smith-work is used.

The construction of steam-hammers which are commonly employed for the heavy work in connection with which the steam-hammer is best known, are not well adapted for smiths' use, but the one represented in Fig. 177 is said to be found remarkably convenient and easy of manipulation. The form of the framing allows the smith to stand on three sides with equal facality, so that if standing in the middle of the workshop, men from different sides can with ease bring their work under it. And as the framing consists of two separate standards, with a clear wide space between them, a long bar can be passed between them and laid across the anvil in either direction.

The gearing for working the valves is a combination of "self-acting" and "hand-worked" gearing. The "tappets," or "cams," or "sliding wedge," usually employed in the self-acting gear of hammers, are entirely dispensed with, and thereby the excessive noise and wear which they produce are obviated. The mechanism consists of a hardened roller, fixed upon the back of the "tup," or hammer-head, sliding up and down the face of a curved lever, which is supported at its upper part by a stud, and kept always in contact with the roller by means of a spiral spring; it moves a valve-spindle, and regulating-valve upward and downward at every rise and fall of the hammer. The distance traveled by the piston is regulated by a lever, fixed upon the stud, which carries the curved lever, and by moving which this stud is elevated and depressed, thus altering the points at which the steam is admitted to or liberated from the cylinder. This regulating-lever is fitted on the outside of the framing in a position convenient for handling, and is provided with a guard-plate and spring for retaining it in any desired position. The regulating-valve is in the form of a double piston, hollow through the center, so as to be open from end to end. The steam is admitted and released through a number of ports, arranged around the valve on all sides, so that the valve is held in perfect equilibrium, and as a very slight movement of the valve uncovers a large area of the ports, the steam enters and leaves the cylinder very quickly, and causes the hammer to deliver its blows with great rapidity and force. With a fair pressure of steam, of from about 40 to 60 pounds per square inch, the hammer will, when desired, strike about 250 blows per minute, and the length of stroke can be varied at pleasure from the maximum, 21 inches, down to about 2 inches, the changes being effected without checking the hammer.

For many purposes the self-acting stroke is not so useful as a slow and heavy "dead" blow, in which the steam does not begin to lift the piston until the full force of the blow has been expended. Ordinarily in "self-acting" hammers this quality of blow is either not attainable at all or only imperfectly, and with difficulty; but in this hammer there is a hand-lever in a convenient position, connected directly with the valve, by means of which perfectly "dead" blows can be delivered instantly, the change from "self-acting" to "hand-working" being effected without the slightest interruption. For stamping, punching, and any other purposes for which heavy deliberate blows are required, this is of importance.

The pistons of these hammers are forged in one solid piece with the piston-rod, and fitted with Ramsbottom's steel packing-rings. The "tup" is of hammered scrap-iron, and moves between guides formed in the framing.

The anvil-block is a separate casting of great weight, and turned in the lathe in the part which passes through the base-plate, the hole in the latter being bored out to fit it, thereby preventing the inconvenience caused by the anvil-block moving from its true position or settling down on one side.

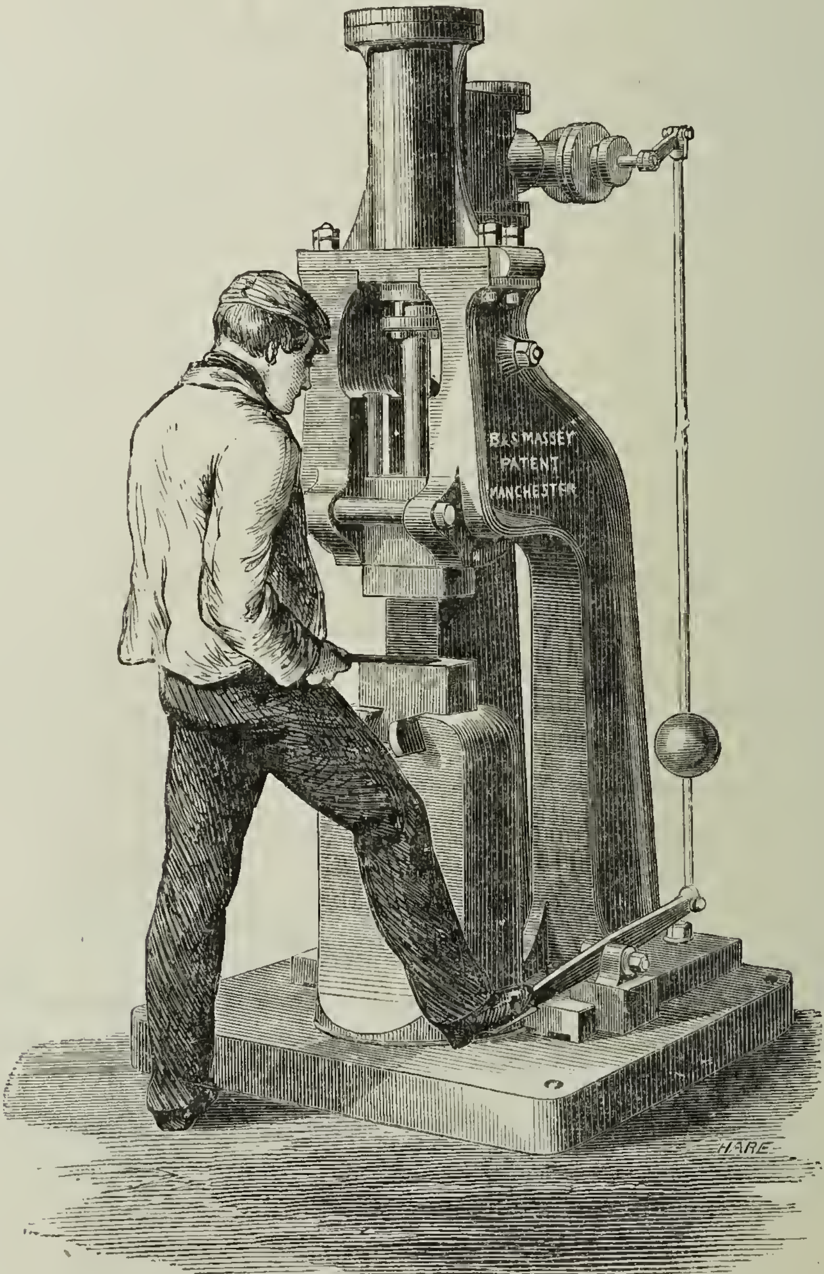


Fig. 178.—Masseys' ½-cwt. steam-hammer.

Fig. 178 is an illustration of a ½-cwt. steam-hammer; is much used for forging files, spindles, bolts, cutlery, and other small work.

For file-forging, the first steam-hammer known to have been used was, it is said, made by B. & S. Massey for Messrs. T. Turton & Sons' Sheaf and Spring Works, Sheffield; and though the opposition of the trade-unions threw much difficulty in their way, the use of small steam-hammers is rapidly superseding hand-forging. For many purposes, these little hammers are fitted with "foot-levers," by means of which the workman is enabled, without assistance, to start and stop them, and to regulate their speed and force, while leaving both hands free for the manipulation of his work.

For other purposes, when there is a greater variety in the shape of articles to be made with the hammer, the foot-lever is omitted, as the workman could not conveniently make use of it. This hammer, it is stated, can be worked up to a speed of about 400 blows per minute. The maximum length of stroke is 11 inches.

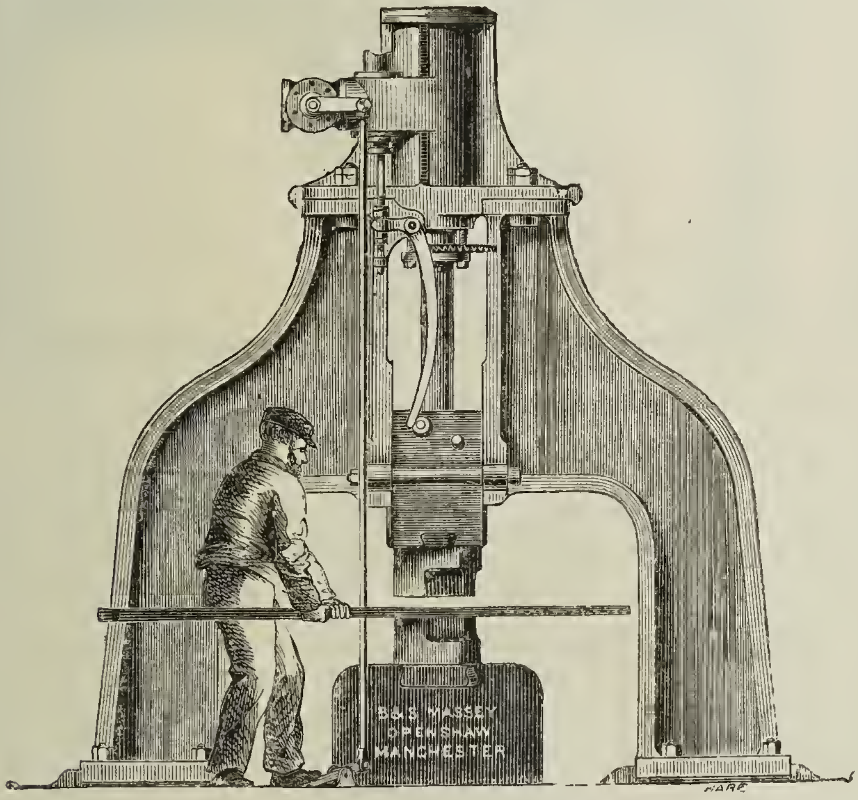


FIG. 179.—Massey's steam-tilting-hammer.

The 1½ cwt. steam-hammer is used for medium smith-work. The construction of this hammer is, with small exceptions, similar to the 5-cwt. one already illustrated in Fig. 177. It is used for the lighter kinds of general smith-work, such as bars and shafting, up to about 3 inches in diameter.

This hammer was exhibited at work at the Exhibition, the 5-cwt. hammer being too large to work there, on account of the vibration produced by its powerful blows.

Fig. 179 represents the steam-tilting-hammer for steel. They are of great strength in all their parts, with large cylinders, short stroke, simple, self-acting valve-gear, and very rapid action. The sizes range from 1 to 20 cwt.

Fig. 180 illustrates the steam-hammer for wheel-making, copper-work, &c. For any work which requires great width and height under the framing, this form of hammer is specially suitable. For wheel-making and heavy copper-work, the hammer is usually worked by hand, as shown in the engraving, the gear being so arranged as to leave the space below the framing quite unobstructed. The sizes are 10 to 15 cwt. They are capable of striking 300 blows per minute. The height under the framing is 11 feet.

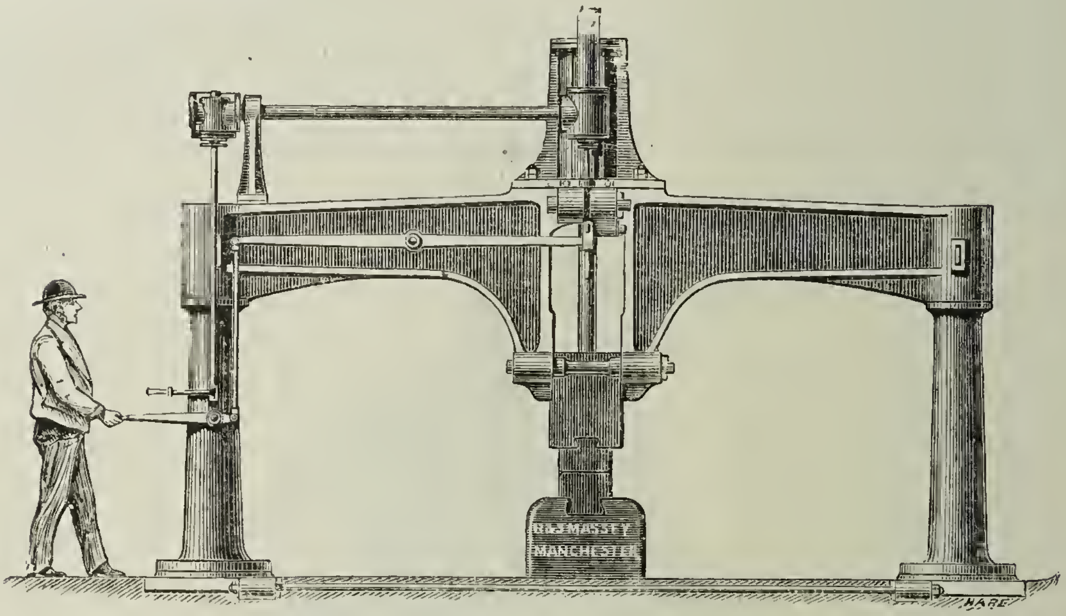


FIG. 180.—Massey's steam-hammer.

Fig. 181 illustrates the 3 cwt. special steam-stamp. This is a steam-hammer of peculiar arrangement, introduced years ago by the Messrs. Massey, and specially designed for forging articles of which large quantities are used, by means of dies cut to the form of the finished article. The stamp is not self-acting, but is regulated either by the foot or by the hand. When left to itself with the steam turned on, it rises to the top of its stroke and remains in that position until the valve is brought down by the hand or foot of the attendant. It then delivers a single "dead blow," and rises again, as before, leaving the lower die clear for the removal of the finished article and the introduction of the hot iron for a new one. The upper die is fixed rigidly in the tup or hammer-head, the lower one being adjusted by strong poppet-screws until it exactly coincides with it. The tup is fitted between slide-bars which guide it down upon the lower die, and, with a stamp of adequate size, the forging can be finished at a single blow with a great degree of accuracy. Special arrangements are introduced for facilitating the adjustment of the dies, for removing bolts and similar articles from the dies, for preventing the piston from striking the cylinder-cover, and for adjusting the slides so as to compensate for the wear caused by friction.

The 5-cwt. stamp will, with great ease, as claimed by the exhibitors, make a bolt $1\frac{1}{4}$ inches diameter, with large square head $2\frac{3}{4}$ inches diameter and 1 inch thick, and with very deep square neck, at *a single blow.*

The principal sizes of these stamps weigh from $\frac{1}{2}$ to 10 hundredweight.

Fig. 182 illustrates some of the work done by these tools, such as

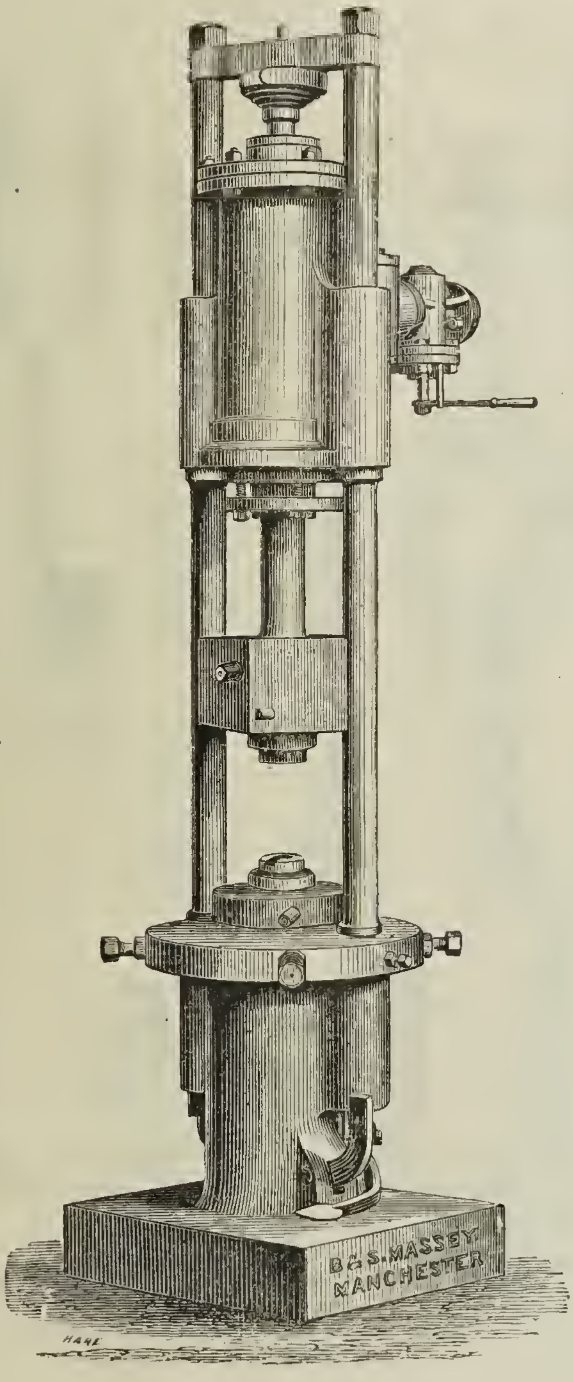


Fig. 181.—Massey's steam-stamp.

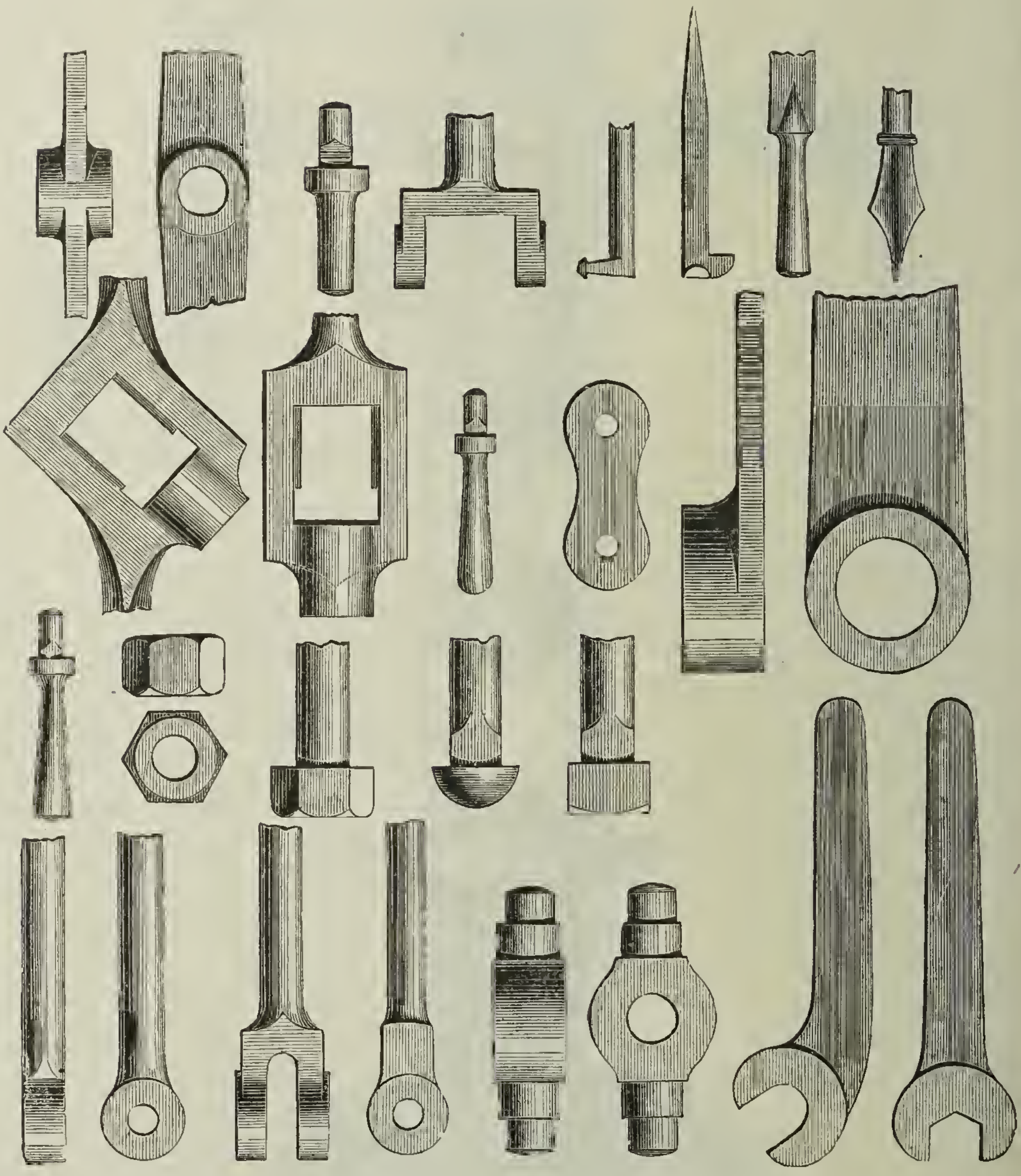


FIG. 182.—Specimen forgings made with Massey's steam-stamps.

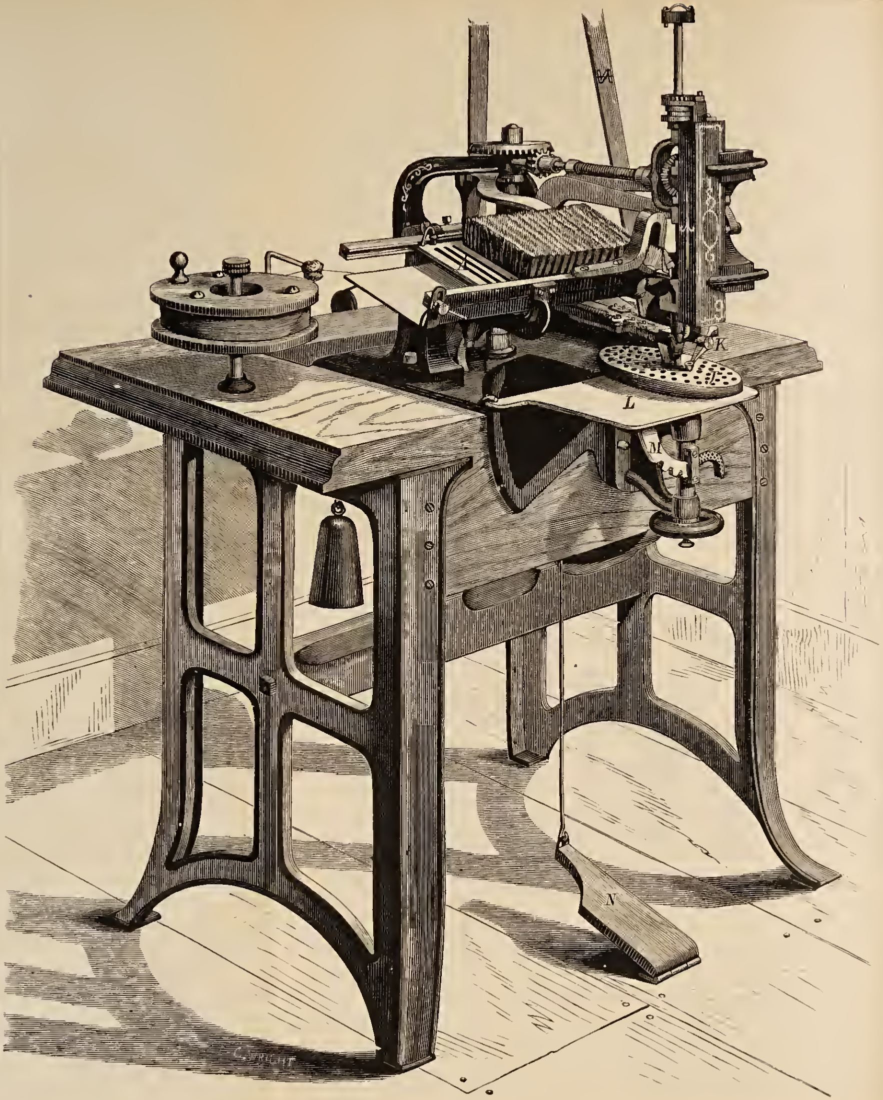


Fig. 183.—Woodbury brush machine.

screw-keys, spanners, bolts, rivets, nuts, gun-locks, joint-ends, spear-heads, levers, bosses, and other pieces.

290. Mr. H. C. Covert, of New York, exhibited the WOODBURY BRUSH-MACHINE, in operation in the American section, making brushes of every size and kind. This machine (Fig. 183) is purely automatic. It forms the bristles into bundles of suitable size, winds a fine wire about the part which is to enter the back in such a way that it forms a screw-thread. It is then screwed into the back, and so firmly that no force can extract it by a direct pull, the bristles themselves breaking before the hold in the back can be broken.

The material to be worked in this beautifully-ingenious machine is first drawn in between the teeth of a comb, A, Fig. 183. This comb is taken out of the machine for this purpose, and, there being duplicate combs, empty ones can be filled while the machine is at work, so that it may run without intermission. The comb, when placed in the machine, slides in guide-ways, being actuated by a traverse motion, which, as fast as one space is emptied of its material, brings another up to the mouth of a twisted channel, B, into which the bristles or other fibrous material is forced by a feed-movement very much resembling the four-motion feed on sewing-machines, the teeth of which engage the entire rank of fibers.

The office of the twisted channel is to bring the rank of fibres from the vertical into the horizontal position. In this position it reaches the divider C, where a portion of the rank of fibres is compressed by a spring, so as to insure the proper quantity in the bunch which the divider separates. This divider, which is attached to and forms a part of the tube which carries the bunch, has imparted to it, by suitable mechanism, a vertically-reciprocating movement. As it rises, the peculiarly-shaped point D separates from the rank of bristles enough to form a bunch, and as the separated portion cannot rise, the divider, in its further upward movement, brings the bunch down along the inclined way or channel E to the bottom F of the way; here it lies directly under the doubling and twisting plunger G, shown in details in Figs. 185 and 186.

The plunger G now descends, and, engaging the bunch in a hollow in its lower end, forces it down and doubles it in the manner shown in Fig. 185.

Meanwhile the wire I, Fig. 186, has been drawn off and straightened, preparatory to being thrust through a slot in the plunger at H, Fig. 185, and between the ends of the looped bristles, which being accomplished, it is cut off in a short length, as shown in Fig. 186.

The plunger and tube now descend together to the block, carrying with them both bunch and wire. On the interior of the tube is cut a female screw-head. The plunger is caused to turn on its vertical axis during the descent, which winds the wire about the bunch of bristles in the form of a screw-thread, as shown in Fig. 186. Continuing the same

Fig. 184.

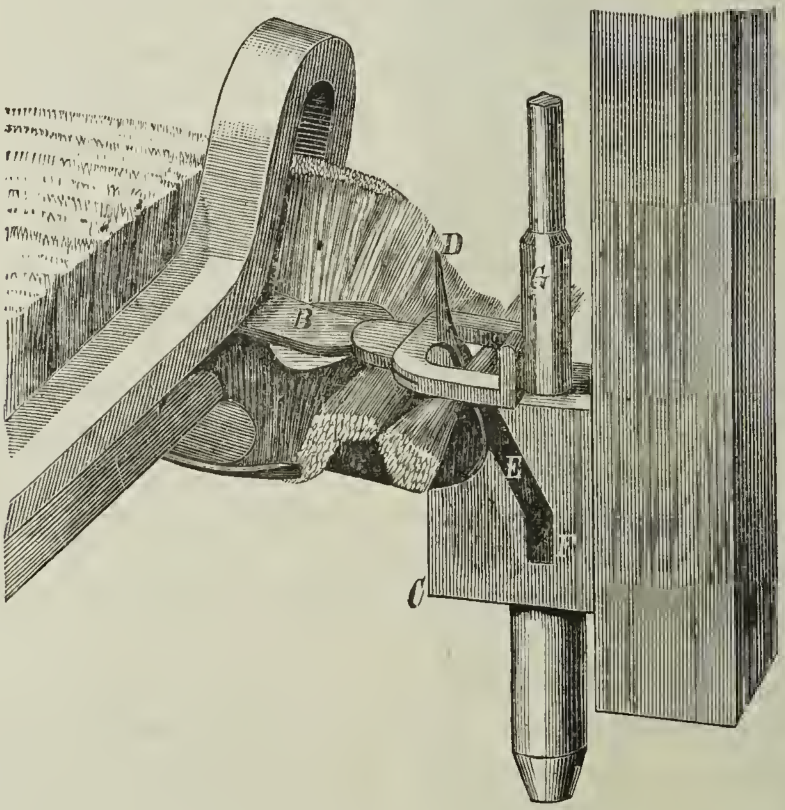


Fig. 186.

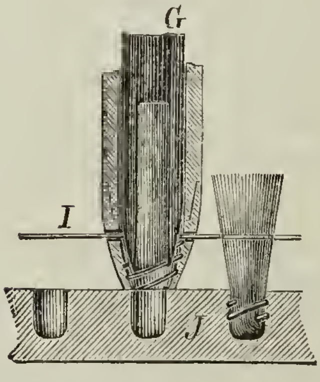
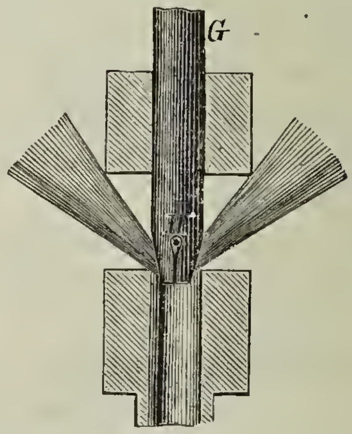


Fig. 185.



Woodbury brush-machine.

rotating movement without descending farther, it then screws the wire bunch into the block J, Fig. 183, the lower cut end of the wire plowing a thread in the hole; then when the bunch has entered to a proper depth, a slight turn of the plunger in the reverse direction takes the twist out of the bristles, and the upper cut-end of the wire engages the wood. The plunger is then withdrawn, and the same operation is gone through with a succeeding bunch, and so on, till all the holes in the block are filled.

The block lies on its back on a table made adjustable to any angle, so that the bunches may be inserted obliquely as required, the pitch of the table being regulated by the notched arc M and other appliances, readily manipulated by the operator.

While one bunch is being inserted, the point of the guide K is inserted into the next suceeding hole by the operator, and as soon as the bunch is inserted, this guide automatically draws the hole with which it is engaged directly under the plunger to receive its bunch, accurately centering it and obviating the possibility of mistake. The guide then releases itself from the hole, which immediately receives its bunch, and so on, till the block is filled.

Seventy-five to eighty bunches per minute is said to be an easily maintained rate.

The machine works, as stated, tampico and all other vegetable fibre used for filling brushes, as well as bristles, and the knots or bunches are inserted in hard rubber with the same facility as in wood.

An ordinary scrubbing-brush block can be filled in one minute.

291. A collection of boot and shoe machinery exhibited by **Horace H. Bigelow**, of Worcester, Mass., and by the **Reversible Boot-Heel Company**, of Providence, R. I., was hardly less ingenious, and attracted nearly as much attention as the pail and barrel making machinery already described.

The accompanying cuts will illustrate the machinery used by the Bigelow Heel Compressing and Attaching Company. By their system of compressing heels, a more uniform, solid, and perfectly shaped heel is claimed to be obtained than by any other method in use.

The lifts are first tacked together, after which they are placed in the machine and compressed in a mold of the required size. Fig. 187 illustrates the heel-compressing machine. "Thus," says the inventor, "the heel is made thicker by being compressed on the sides, gaining thereby a lift on each heel. Instead of wasting the stock by trimming it off; it is compressed into the heel. The holes are made in the heel and nails set while the leather is under pressure. A better heel can be made from the same stock, with either pieced or whole lifts, than by any other process, while at the same time the heel is more solid, uniform, and durable. It is not necessary to use a rand on any kind of boot or shoe having a low shank. The heel being concaved sufficiently in the machine to fit on the shank, uniformity in nailing is secured. A better and smoother burnished edge

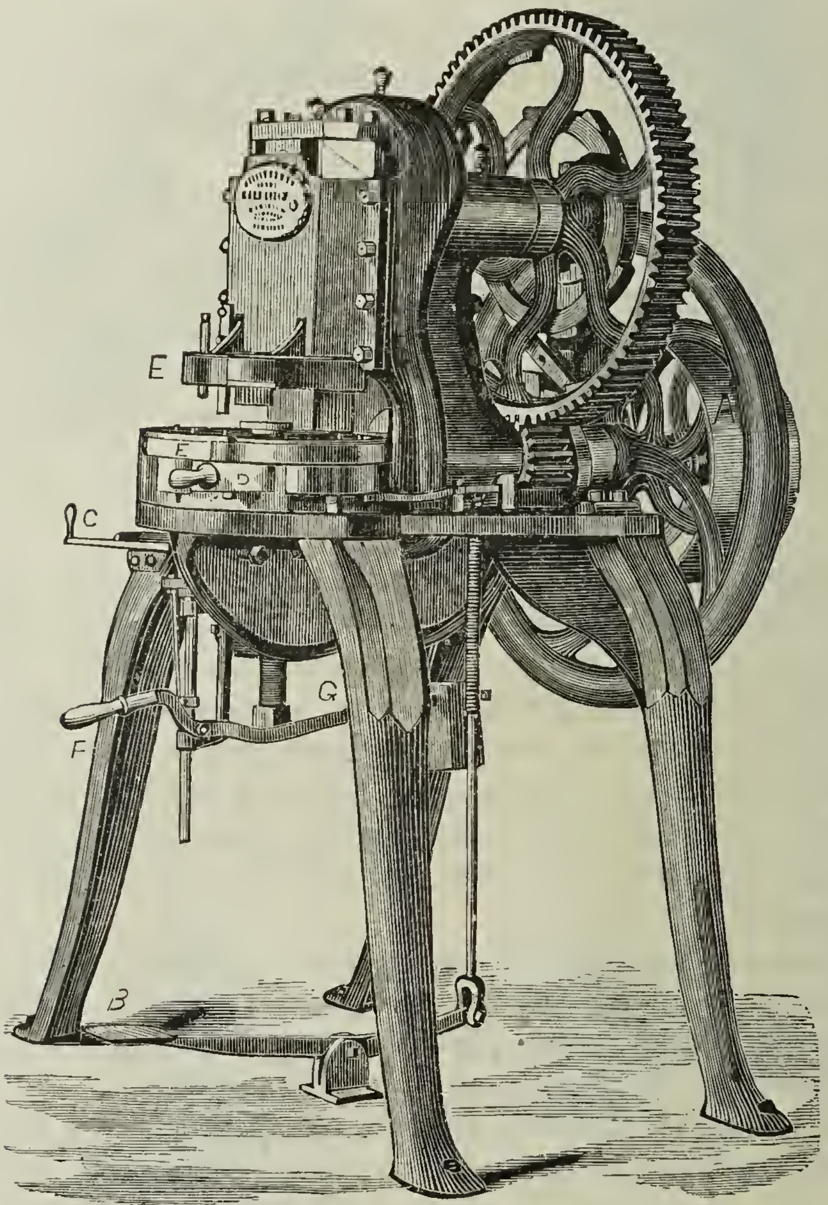


FIG. 187.—Heel-compressing machine.

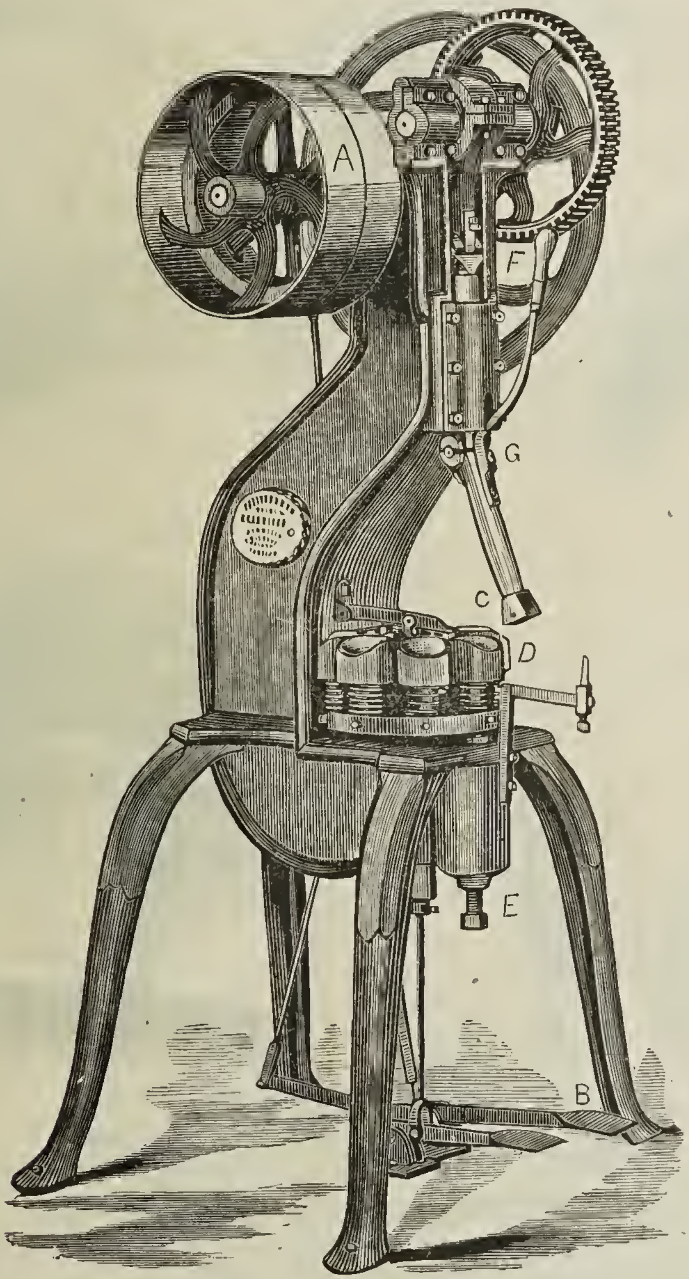


FIG. 188.—Heel attaching machine.

can be obtained. Great rapidity in its operation is an important feature; a man can put on with a hammer 400 pairs a day of compressed heels, effecting a great saving of labor. This machine compresses 1,500 pairs daily." The compressing-machine has two 18-inch pulleys, 4-inch face each, (tight and loose,) and runs 180 revolutions per minute.

Fig. 189.

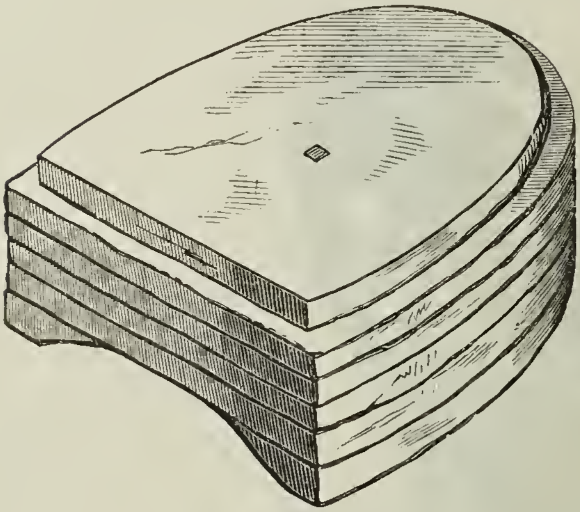


Fig. 190.

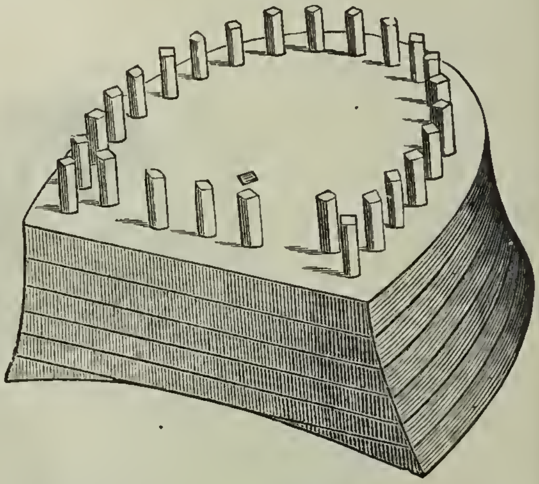


Fig. 191.

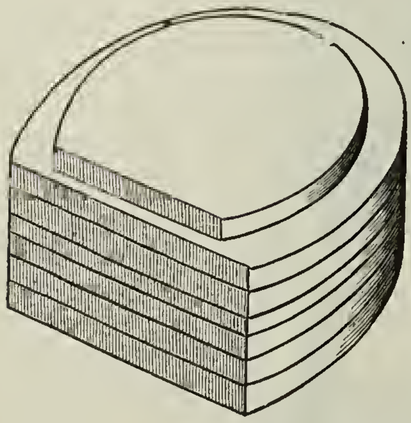
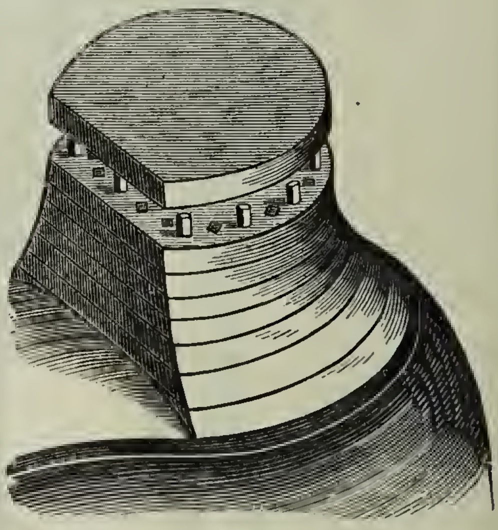


Fig. 192.



Heels in process of construction.

Fig. 188 is the attaching-machine, which is used to heel boots and shoes of every description, either nailed or blind-nailed. This machine puts on heels more uniformly and truer than can be done by hand, with a remarkable rapidity of operation, and effects a great saving of labor. It has the merit of simplicity in its construction, and of being easily adjusted to heels of any size. The heels are beveled and need not be smoothed after being put on. One man can heel 1,500 pairs per day. This machine has two 18-inch pulleys, 4-inch face each, (tight and loose,) and runs 180 revolutions per minute.

Manufacturers not having power and those who buy their heels make a great saving by using the compressed heel. They are rapidly attached with a hammer, saving labor in heeling and trimming, and preserving

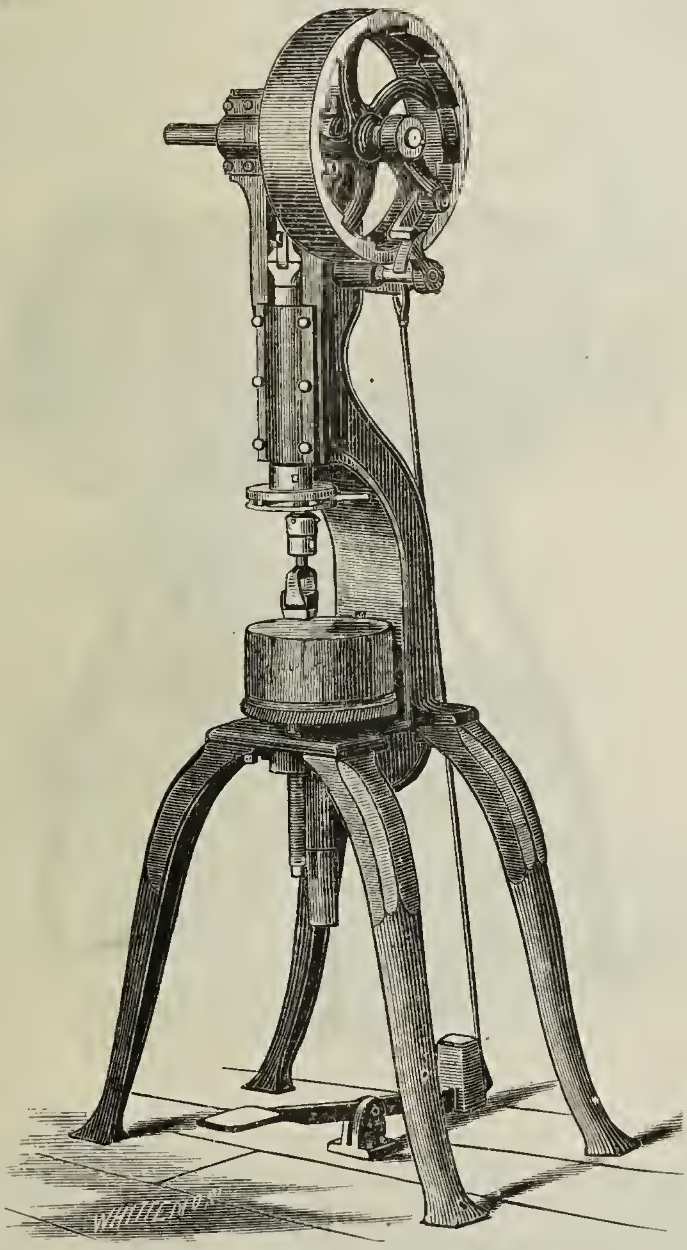


Fig. 193.—Heel-cutting machine.

the uniformity and solidity of the heel, producing better work, and at low cost. Figures 189, 190, 191, and 192 represent the heel in various stages of construction, from the blank heel to that ready to receive the blind top-lift, which is also adjusted by the attaching-machine.

Fig. 193 represents the heel-cutting machine, which is adapted for cutting outsoles, insoles, heeling, counters, shanks, &c., and can be used with dies having handles or without. The large size has a 20-inch circular revolving block; the die is fastened in a chuck over the block, and can be moved about as desired. The block is worn evenly by the constant revolving motion; the wear is taken up by raising the screw under the machine. The small machines are simple in construction, and can be operated by a boy or girl.

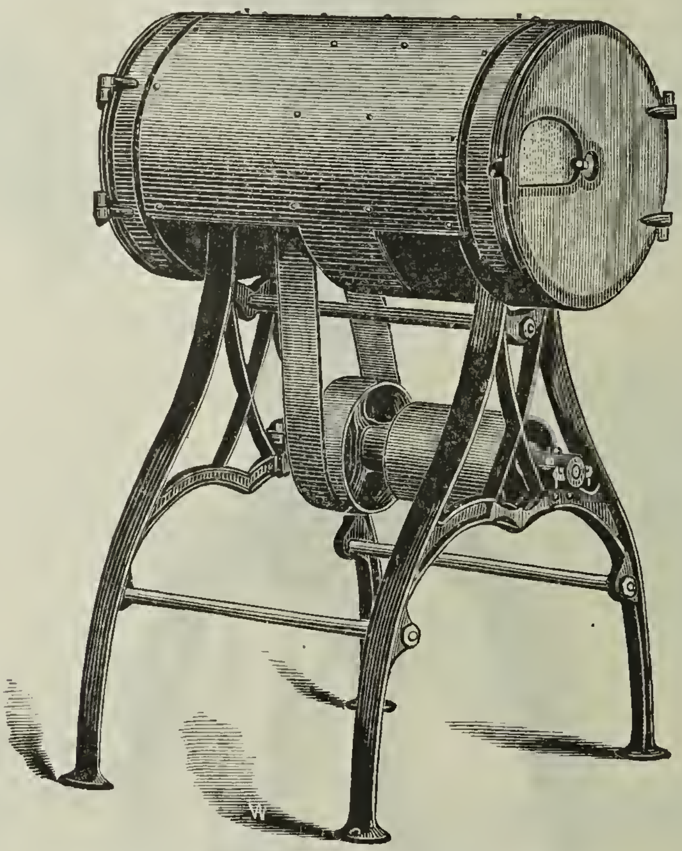


FIG. 194.—Heel-filing machine.

Fig. 194 represents the heel-filing machine, which has an arbor passing through the cylinder, and on each end of the shaft an emery-wheel 14 inches in diameter. The heels are filed on the face of the wheels. The cylinder has a fan inside which carries away the dust.

If desired, an operator can work on each end of the machine.

The wheels are covered with glue and emery; as the emery wears off another covering can be added, and so continued.

The wheels are cleaned by soaking in water; the emery is saved and used again.

Figs. 195–199 represent the different chucks used in the cutting-machine. Fig. 195 is used for holding a heel-die, with raised handle. When the die is filled with the lifts, the operater removes them from the

Fig. 195.

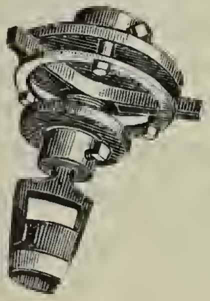


Fig. 196.

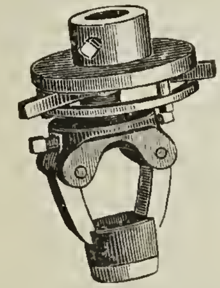


Fig. 197.

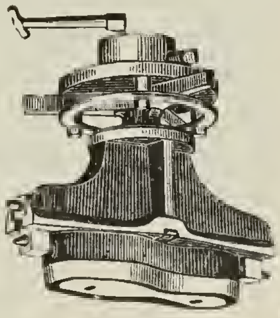


Fig. 198.

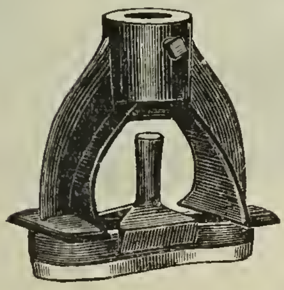
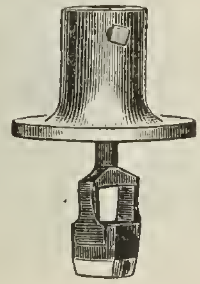


Fig. 199.



Chucks for cutting-machine.

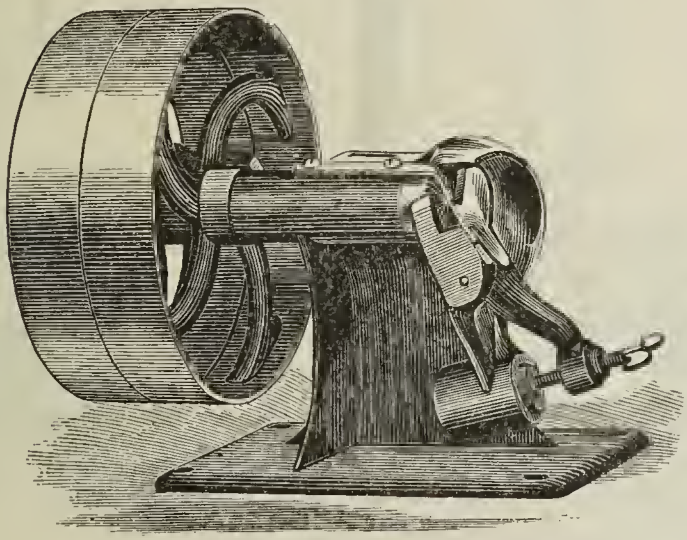


Fig. 200.—Rand-turning machine.

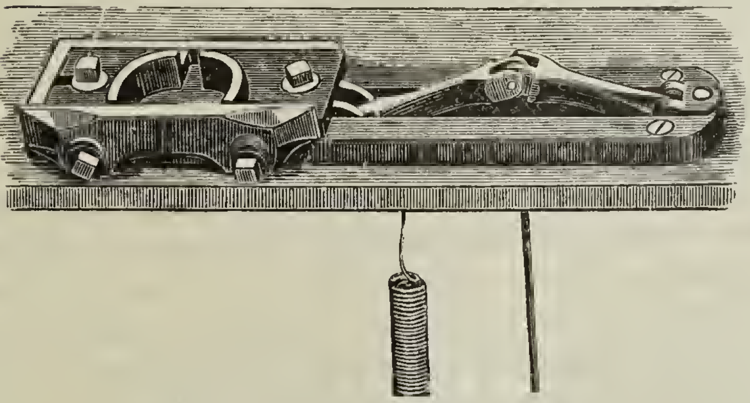


Fig. 201.—Heel-building machine.

top. Fig. 196 is used for holding a die without handle, for cutting heel-lifts or shank-pieces. The pieces are removed as in Fig. 195. Fig. 197 is used for holding a sole-die without handle. The die has a spring to throw out the sole and leave it on the cutting-block. Fig. 198 is used for sole-dies with or without handles, the die passing into the opening in the chuck. The dies for this chuck are not attached as in the former, and can be changed easily. Fig. 199 is used for handle-dies, for cutting heeling, shanks, or soles. The die for this chuck is attached.

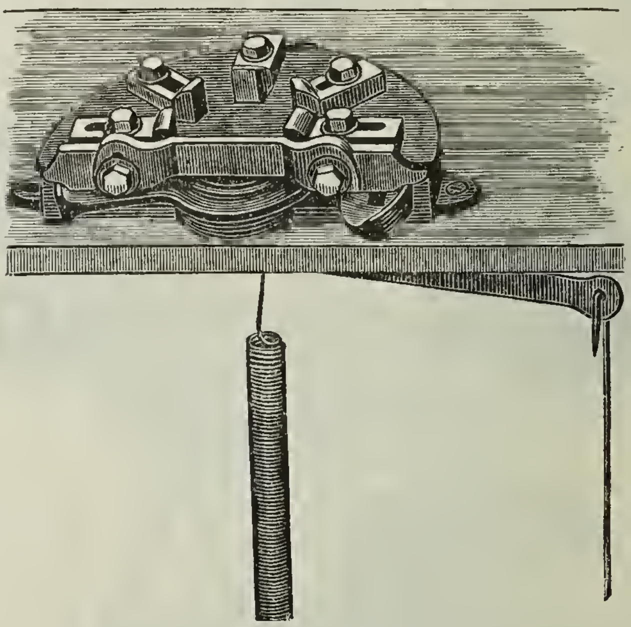


FIG. 202.—Adjustable heel-building machine.

Fig. 200 illustrates the rand-turning machine. This machine is very valuable, in connection with the compressing-machine, when a rand is used. A good rand can be turned at the rate of 6,000 per day.

Fig. 201 represents a heel-building machine with jaws, and Fig. 202 an adjustable heel-building machine. These machines are well adapted for tacking up heels, either whole or pieced lifts. The jaws in Fig. 201 are made to correspond with the various sizes of heels, and of Fig. 202 are movable.

Fig. 203 illustrates a machine for cutting off rands, and is used in connection with the compressing-machine.

Fig. 204 is a "jack" used in shaving the heels off smooth.

292. TILGHMAN'S SAND-BLAST was anxiously looked for by the jury, but, although finally set at work, was not put in operation until after their adjournment.

The sand-blast process has attracted more attention from both scientific men and mechanics than probably any contemporary invention. It was first exhibited in the United States at the American Institute Exhibition of 1871, and a committee of judges, consisting of three gentlemen selected from among our most distinguished men of science, recommended the award of the great Medal of Honor of the Institute.

The judges, Messrs. F. A. P. Barnard, president of Columbia College;

Alfred M. Mayer, professor of physics in the Stevens Institute of Technology, and Henry Morton, president of the latter college, reported that the process was "designed to execute ornamental inscriptions in *intaglio* or relief; or complete perforations in any kind of stone, glass, and other hard and brittle substances; or to cut deep grooves in natural rocks, in order to facilitate the process of quarrying; or to make circular incisions around the central mass of rock in the process of tunneling; or to remove slag, scale, and sand from the surfaces of metal-castings; or to clear the interior surfaces of boilers or boiler-tubes of incrustations; or to cut ornaments or types from wood as well as stone; or to depolish the surface of glass, producing, by the use of stencils or other partial protections, such as the bichromatized gelatine of photographic negatives, every variety of beautiful figures, including copies of the finest laces and the most delicate line-engravings; or to prepare copper plates in relief for printing, by making gelatine photographic pictures upon smooth surfaces of resin or pitch, cutting them out by the blast and afterward molding from them and electrotyping the molds.

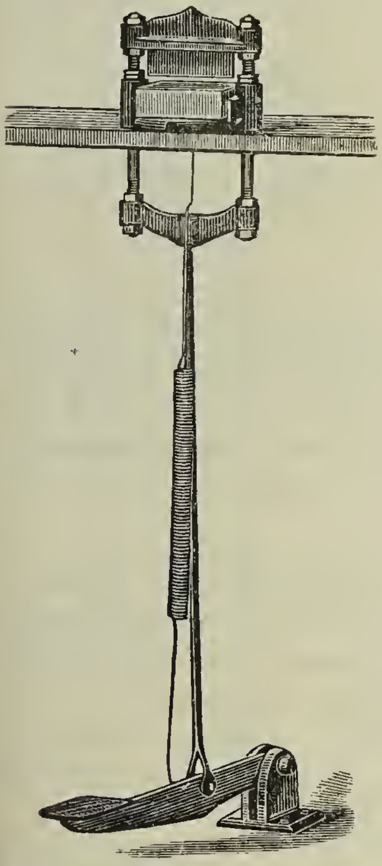


FIG. 203.—Machine for cutting rands.

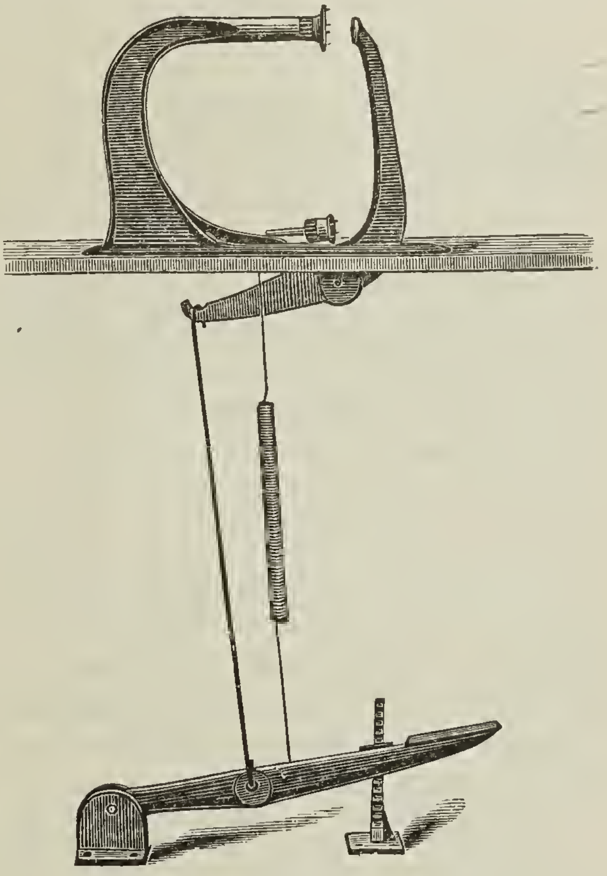


FIG. 204.—Jack for shaving heels.

"This process is without precedent.

* * * * * * * *

"The utility of this invention is apparent in the statement above given of the processes to which it is applicable. It is regarded by the judges as being one of the most remarkable and valuable inventions which the age has produced.

"Considering, therefore, the great originality, importance, and value of this process, and the great variety and diversity of applications, both useful and ornamental, of which it is capable, the judges unanimously recommend that the great Medal of Honor of the Institute be conferred upon the ingenious inventor, as a well-merited distinction."

Professor Egleston, experimenting upon the effect of the sand-blast on harder materials than the sand itself, found the following as the loss of weight and the time required to produce it:

Material.	Weight.	Loss.	Time.
	Grains.	*Grains.*	*Min.*
Corundum	1. 49000	1. 16979	½
Emery	16. 65000	4. 9532	1
Topaz	2. 0970	1. 9707	1
Topaz, (pebble)	9. 774	2. 1499	1
Black diamond	1. 2607	. 0372	3
Do	1. 2235	. 0497	5
Do	1. 2607	. 0869	8

The emery contained some iron-ore.

A "jet of sand" impelled by steam of moderate pressure, or even by the blast of an ordinary fan, depolishes glass in a few seconds; wood is cut quite rapidly; metals are given the so-called "frosted" surface with great rapidity. With a jet issuing from under 300 pounds pressure, a hole was cut through a piece of corundum, 1½ inches thick, in 25 minutes. Etching on glass is beautifully done.

The fracture of a hard body like diamond by a comparatively soft body like sand seems, at first thought, very remarkable; yet, it is daily paralleled in ordinary experience, and is illustrated most strikingly by the fact that "water continually dropping will wear away a stone."

Prof. Osborne Reynolds was the first to publish an analytical investigation[*] of the principles involved in this machine. [†]

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[*] Philosophical Magazine, Fourth Series, Vol. 46, No. 307, p. 337.

[†] The following is the basis of the analysis: At the time of impact the pressure is independent of the magnitude of the masses, and is determined by their density and hardness. The character and mode of action of the surface-particles, and not of the whole mass, determines, at very high velocities, the effect of impact. Then, if

v = the velocity of surface-particles of a body;
λ = its modulus elasticity;
d = the "heaviness," *i. e.*, the weight per cubic foot;
p = pressure at contact in pounds per square foot;

$$p = v\sqrt{\frac{\lambda d}{g}}$$

For, if x represent the original distance of a surface point of impact from a given point, P, within the mass, and $x - \xi$ its distance after a time, t,

$$\frac{d}{g} \times \frac{d^2 \xi}{d t^2} = -\frac{d p}{d x} \text{ and } p = -\lambda \frac{d \xi}{d x};$$

hence,

$$\frac{d^2 \xi}{d t^2} = \frac{g\lambda}{d} \cdot \frac{d^2 \xi}{d x^2}$$

and

$$\xi = f\left(\sqrt{\frac{g \lambda}{d}}\right) - x.$$

293. **THE WEST TIRE-SETTER** (Fig. 205, page 320,) was exhibited by the Mowry Axle and Machine Company, and was one of the most striking novelties seen, even in the United States section.

It consists of a strap made up of several thicknesses of thin steel, and capable of being "set up" by a very powerful screw worked by a belt. A wagon-wheel placed within this ring or strap, with its tire perfectly loose, was clasped by it, and a few turns of the screw drew the strap so tight as to "upset" the tire, although perfectly cold, securing it more firmly than it would have been if shrunk on in the usual way, and producing, at the same time, any desired dishing of the wheel. It worked very finely.

The avoidance of the usual injury to the wheel by burning, and of the consequent insecurity of hold due to this injury of the surface of the wood where in contact with the tire, are important and evident advantages due to the use of this machine. It was considered one of the best tools exhibited.

294. **SAMUEL A. MILLER** exhibited a rough but effective little machine for bending stove-pipe elbows, which particularly interested several members of the jury.

When $x = 0$

$$\xi = f\left(\sqrt{\frac{g\,\lambda}{d}}\,t\right),\quad \frac{d\,\xi}{dx} = -f^{1}\left(\sqrt{\frac{g\,\lambda}{d}}t,\right.$$

$$\frac{d\,\xi}{d\,t} = \sqrt{\frac{g\,\lambda}{d}}.f^{1}\left(\sqrt{\frac{\lambda}{d}}\,t\right),\ \text{and}\ \frac{d\,\xi}{d\,t} = v;$$

then

$$p = \lambda\,f^{\cdot 1}\left(\sqrt{\frac{g\,\lambda}{d}}\right)t\,\Big) = \sqrt{\frac{g\,\lambda}{g}}\,v.\quad \text{Q. E. D.}$$

If

v = velocity of impact;
λ^{1} = elasticity of the second body;
d^{1} = density of the second body;

$$p = \frac{\sqrt{\lambda^{1}\,d^{1}}}{\sqrt{g}}.(u - v);$$

and, when the material is the same,

$$v = \frac{u}{2}.$$

If they were of different materials,

$$p = \sqrt{\frac{\lambda\,d}{g}}\,v = \sqrt{\frac{\lambda^{1}\,d^{1}}{g}}(u - v),$$

$$v = \frac{\sqrt{\lambda^{1}\,d^{1}}}{\sqrt{\lambda\,d} + \sqrt{\lambda^{1}\,d^{1}}}\,u.$$

In the case of liquid impact]

$$p = \frac{v^{2}\,d}{2\,g}.\,v^{2},$$

and

$$\frac{d^{1}}{2\,g}\,(u - v)^{2} = \sqrt{\frac{\lambda\,d}{g}}\,v.$$

It consisted of a pair of sets of clamps which seized the pipe, and, turning on horizontal axes, forced it to bend at each operation through a small angle. The pipe was then released and a new hold taken at a point a little farther along, and the operation repeated until the pipe had been given the required bend.

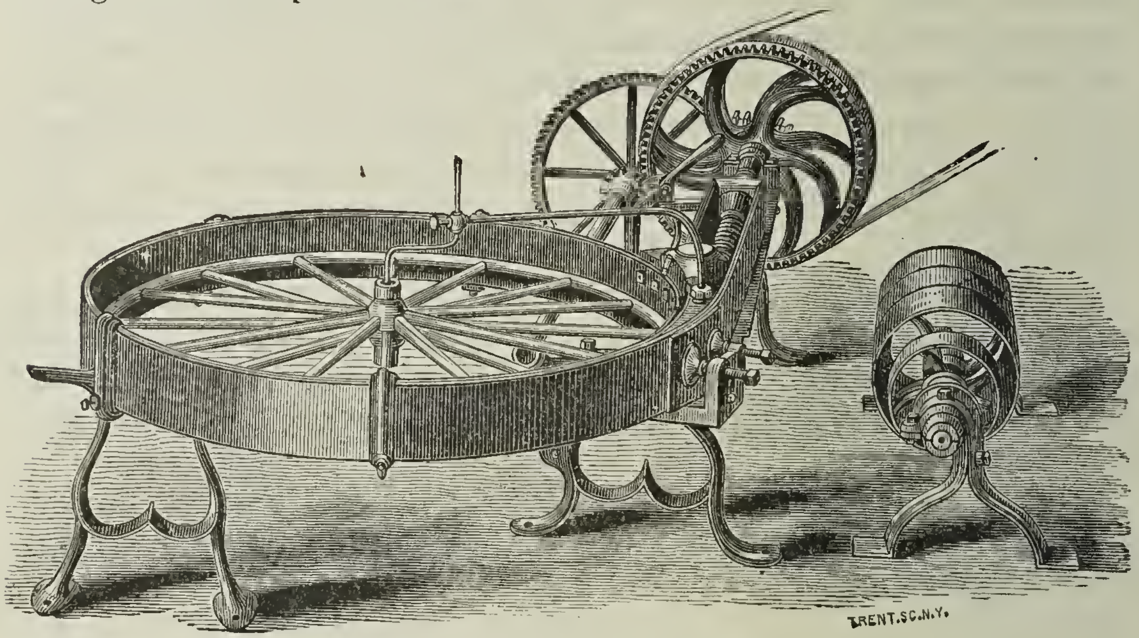

FIG. 205.—West's tire-setter.

ALBIN WARTH exhibited in the United States section a machine for cutting cloth, which seemed remarkably well adapted for cutting out clothing for makers of "ready-made" stock or for use wherever large quantities of cloth are to be cut.

It consisted of a knife rising and falling with a rapid reciprocating

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In illustration, glass striking upon glass, and

$$d = d^1 = 150$$
$$\lambda = 1,152,000,000$$
$$p = 1,440,000;$$

$$v = \frac{8 \times 1,440,000}{\sqrt{150 \times 1,152,000,000}} = 27\tfrac{1}{2} \text{ feet per second,}$$

which would just crush the surface, and, as Professor Reynolds notes, corroborates the statement that a pressure of blast of 4 inches of water is sufficient to produce cutting on glass.

For solids,

$$p = \frac{\sqrt{\lambda\, d}\; v}{\sqrt{g}} + \frac{v^2\, d}{2\, g},$$

in which the last quantity in the second member of equation has no effect, as it is equilibrated by the inertia of the surface-particles.

Using lead,

$$d^1 = 712$$
$$\lambda^1 = 720,000 \times 144$$

but the maximum resistance by lead to crushing only reaches 576,000, and this value is taken for λ. Then $u = 250$ and $v = 30$, nearly, indicating that it requires eight times as much velocity to abrade glass with lead as with glass.

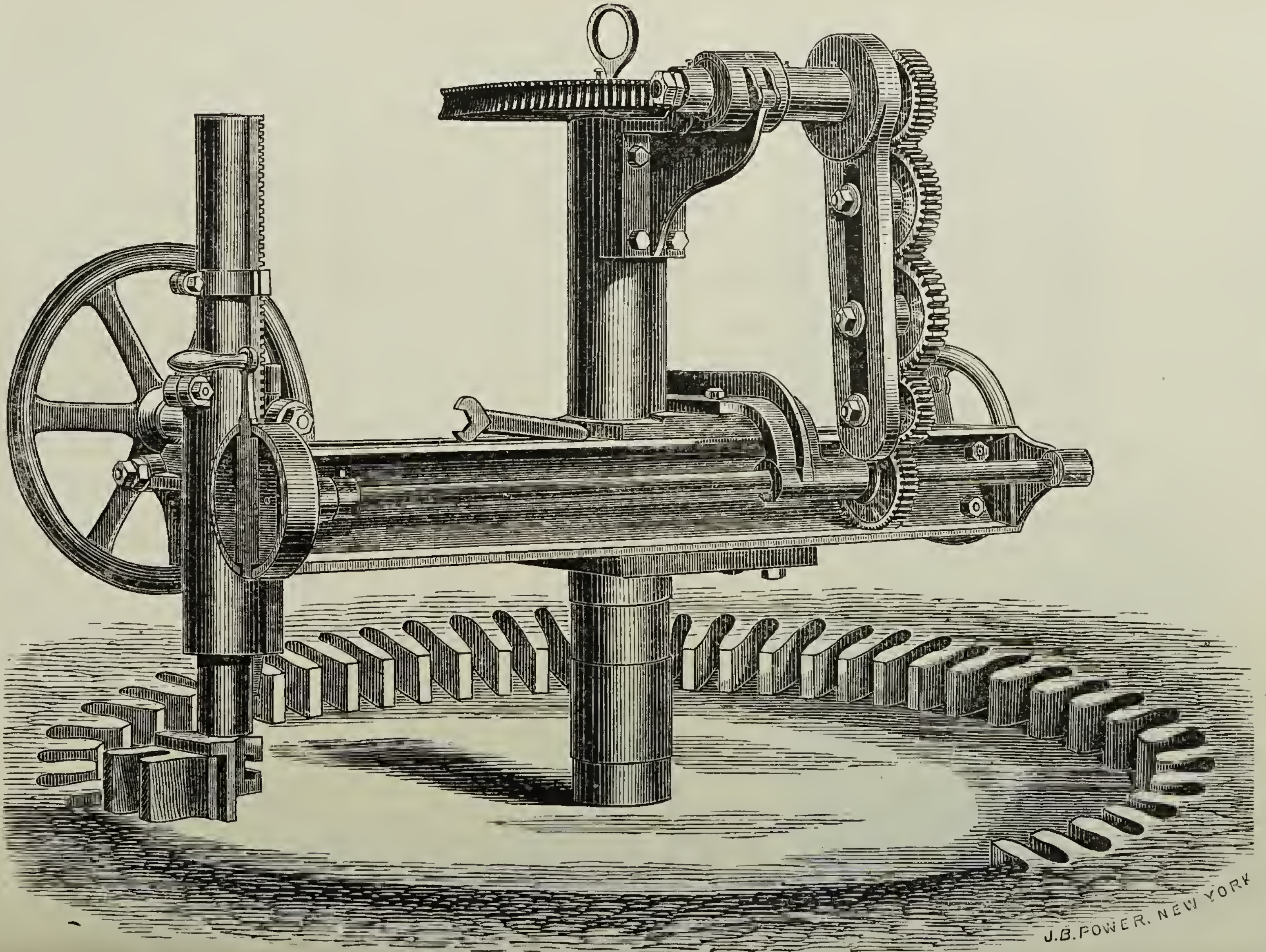

FIG. 206.—Scott's gear-molding machine.

motion, its inclined edge cutting the cloth with the same action as is obtained with ordinary shears. The cloth, single or in many thicknesses, was drawn against this knife, the operator following the line marked on its surface with the cutter's chalk.

In a later modification the device is made even more convenient and more rapid in its operation. The knife and its stand are made very light, and mounted on a broad base, which is moved about on the table in any direction almost as readily as the cutter's shears. Motion is communicated to the knife by round belting carried along a simple and ingenious combination of link-work, which accommodates itself to a wide range of traverse of the knife. Cutting a dozen thicknesses of heavy woolen goods with much less effort on the part of the workman than is ordinarily demanded in cutting a single thickness with shears, and working with vastly greater rapidity, this neat little device accomplishes a most important advance in its department.

The measuring-instruments of Messrs. DARLING, BROWNE & SHARPE were among the finest of all exhibits of accurate workmanship and fine finish. They exhibited a very complete assortment of their rules, gauges, and other instruments. They have no rivals at home or abroad in the manufacture of the finer classes of mechanics' measuring-tools.

THE MORSE TWIST-DRILL COMPANY exhibited their beautiful tools. These neat instruments are now considered as essential to good work in every machine-shop in the United States, and are gradually finding their way into European workshops.

295. A very interesting and valuable invention was exhibited in the British section by George L. Scott. This was the SCOTT GEAR-WHEEL-MOLDING-MACHINE, illustrated in the accompanying engraving, Fig. 206, which is furnished by the agents in the United States.

It consists of a strong column mounted upon a base-plate, which latter is imbedded in the sand below the matrix of the mold to be made. The column carries a cross-head which can be turned in the horizontal plane by the worm and gear seen at the top. A handle seen at the extreme right turns a series of change-wheels, by means of which the arc through which the arm swings may be made any desired fractional part of the circle, as in that more familiar machine, the gear-cutter.

At the extremity of this arm or cross-head is a vertical bar, which may be conveniently elevated or depressed by a handily-arranged worm-wheel.

It may also be carried inward toward the column, or outward, as may be desired, by a screw which is moved by a hand-wheel, seen at the extreme left.

On this vertical bar, at the lower end, is a plate, to which may be secured the patterns—two teeth such as it is proposed to use in the wheel to be made.

The method of operation is as follows:

The pattern of the teeth being properly secured to the foot of the sliding vertical bar, the latter is adjusted horizontally until the pitch-line on the teeth comes precisely to the proper distance from the center of the main column, and thus swings in the pitch-circle. The bed is properly prepared by smoothing it up at the level of the lower edge of the proposed rim of the casting, seen in the illustration. The bar carrying the pattern is next lowered until the lower end of the latter touches the bed. The two teeth then are in position, and the intervening space is molded and the ends of the teeth make their impress. Raising the bar until the pattern clears the sand, the molder next turns the handle until the index-wheel has thrown the cross-head through an arc corresponding with the pitch, and the bar then being dropped, one tooth falls into the space between a tooth already molded and its neighbor. The next tooth is then formed, and the process continuing, the whole rim is finally completed. The machine is then removed, and the wheel center and arms are molded in the usual way, and the casting is made.

The rapidity and exactness with which this machine can be made to do its work are quite remarkable, and it will undoubtedly find its way into use very rapidly. It is already introduced into the United States by the NEW YORK MOLDING-MACHINE COMPANY.

The great advantages offered by the use of such a machine, aside from the efficiency of the apparatus itself, are the saving effected in cost of the exceedingly nice work of making the patterns of the wheel-teeth; the avoidance of the taper required in making the ordinary pattern so as to "draw" well; the retention of the hard chilled "crust" of the metal, which is far more durable than the finished surface of ordinary teeth which have necessarily been "cut" to obtain the desired accuracy of form, and the avoidance of the risk and damage usually incurred from the working of patterns under the varying hygrometric conditions of the atmosphere.

Hall's bench-vise, described in art. 266, properly belongs in this class of miscellaneous exhibits of machine-tools.

296. MESSRS. JONES & LOUGHLINS exhibited their cold-rolled shafting. This process is shown, by experiments of Major Wade, the late Chief Engineer Whipple, United States Navy, William Fairbairn, and other authorities, to give an immense increase of strength and elasticity and a considerable increase of hardness.

The experiments of the writer have shown this to be accompanied by, and to be perhaps due to, a singular elevation of the elastic limit of the material.*

The following is Fairbairn's tabular statement, followed by others not less interesting and instructive:

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* See Transactions American Society of Civil Engineers, 1874; Journal of Franklin Institute, 1874; Van Nostrand's Eclectic Engineering Magazine, 1874, &c.

EXPERIMENTS ON THE INCREASE OF COHESIVE STRENGTH IN COLD-ROLLED IRON.

Made by William Fairbairn, Manchester, England.

Condition of bar.	Tensile strength per square inch.		Elongation of 10 inches.	Ratio of strength, the black bar being taken at 1,000.
	Pounds.	*Tons.*	*Inches.*	
Black bar from rolls	60, 746	27, 119	2. 20	1, 037
Bar turned down to 1 inch diameter	58, 628	26, 173	2. 00	1, 000
Bar rolled cold to 1 inch diameter	88, 230	39, 388	0. 79	1, 505

REPORT OF COMMITTEE OF THE FRANKLIN INSTITUTE, PHILADELPHIA.

Tensile strength.

Sample No. 1, inferior quality, broke at . . 49,510 pounds per square inch.
Same bar polished and condensed . . . . 66,862 pounds per square inch.
Sample No. 2, broke at . . . . 57,350 pounds per square inch.
Same bar polished and condensed . . . . 92,623 pounds per square inch.

35,273 ; increase, .61.

Torsional strength.

Sample No. 3, $1\frac{5}{16}$ diameter, twisted at a strain of 587½ pounds on a lever 25 inches long.

Same bar polished and condensed, 1¼ in diameter, twisted at a strain of 1,000 pounds on a lever 25 inches long. Increase, 413½ pounds = .97.

REPORT OF MAJOR WM. WADE, U. S. A.

Average results obtained from numerous experiments made with bar-iron rolled while hot, in usual manner, compared with the results obtained from the same kinds of iron rolled and polished while cold, by Lauth's patent process.

	Iron rolled while—		Ratio of increase by cold-rolling.	Average rate per cent. of increase.
	Hot.	Cold.		
TRANSVERSE.—Bars supported at both ends; load applied in the middle; distance between the supports, 30 inches.				
Weight which gives a permanent set of one-tenth of an inch, viz:				
1½ inch square bars	3, 100	10, 700	3, 451	162½
Round bars, 2 inches diameter	5, 200	11, 100	2, 134	
Round bars, 2½ inches diameter	6, 800	15, 600	2, 294	
TORSION.—Weight which gives a permanent set of 1 degree applied at 25 inches from center of bars.				
Round bars, 1¾ inches diameter and 9 inches between the clamps	750	1, 725	2, 300	130
COMPRESSION.—Weight which gives a depression and a permanent set of one-hundredth of an inch to columns 1½ inches long and ⅝ inch diameter	13, 000	34, 000	2, 615	161½
Weight which bends and gives a permanent set to columns 8 inches long and ¾ inch diameter, viz:				
Puddled iron	21, 000	31, 000	1, 476	64
Charcoal bloom iron	20, 500	37, 000	1, 804	
TENSION.—Weight per square inch which caused rods ¾ inch diameter to stretch and take a permanent set, viz:				
Puddled iron	37, 250	68, 427	1, 837	95
Charcoal bloom-iron	42, 439	87, 396	2, 059	
Weight per square inch at which the same rods broke, viz:				
Puddled iron	55, 760	83, 156	1, 491	72
Charcoal bloom-iron	50, 927	99, 203	1, 950	
HARDNESS.—Weight required to produce equal indentations	5, 000	7, 500	1, 500	50

NOTE.—Indentations made by equal weights in the center and near the edges of the freshly cut ends of the bars were equal, showing that the iron was as hard in the center of the bars as elsewhere. (This fact accords with the statement that the density of the metal is not appreciably changed by this process.—R. H. T.)

297. The method of manufacture consists in first reducing the bars in the ordinary manner to a size exceeding by an eighth of an inch or less that to which they are to be finished. They are next allowed to cool, and are immersed in a bath of dilute acid, by which the exterior coating of oxide is removed. They are then washed and sent to the cold-rolling mill. The rolls are very strongly built, and are finished with great accuracy, and given a very fine surface. The bars are passed through the rolls several times until they are brought precisely to gauge. They are turned over at each pass, and, when finished, have all the accuracy of size that could possibly be given by turning; they are at the same time thoroughly burnished.

The demand for cold-rolled metal is quite large. It is used principally for shafting and for finger-bars for mowing-machines.

This process of cold-rolling has been long known to have a remarkable effect in stiffening and strengthening some of the metals. Cold-hammering, which is similar in its effect, has been practiced by blacksmiths from an early date, when they desired to produce stiffness in a piece of iron. Wire-drawing has always been found to harden and stiffen the metal, making it necessary to anneal the wire between successive operations.

298. A similar effect is produced upon some of the alloys. Mr. S. B Dean, of Boston, Mass., was engaged fifteen years ago in experiments upon the strengthening and hardening of bronze for guns by a somewhat similar method. He succeeded in increasing the density from 8.3 to 8.5 in some cases, and augmented the strength fifty per cent., obtaining a metal capable of resisting a tensile stress of above 40,000 pounds per square inch.

More recently General Uchatius, the director of the arsenal at Vienna, has been experimenting in the same direction. Since the return of the writer to the United States, that officer has furnished him a description of the process and results, of which the following may serve as an abstract.*

299. Ordinary bronze for guns is an alloy, consisting of about 90 parts, by weight, of copper, and 10 parts of tin. Since the atomic weight of copper is 63.4, and that of tin 118, the above proportions of the alloy correspond to a combination of 1 equivalent of tin with 17 equivalents of copper. It becomes, however, more exact, if we take 90.6 parts, by weight, of copper, and 9.8 parts of tin. But experiment shows us that it is questionable whether these two metals form a chemical compound in these atomic proportions. When large melted masses of this alloy solidify, it becomes evident that an alloy which is poorer in tin begins to crystallize first where it touches the mold, its composition being about 92 parts, by weight, of copper, and 8 parts of tin, or 1 equivalent of tin to 21 equivalents of copper; while an alloy richer in tin is

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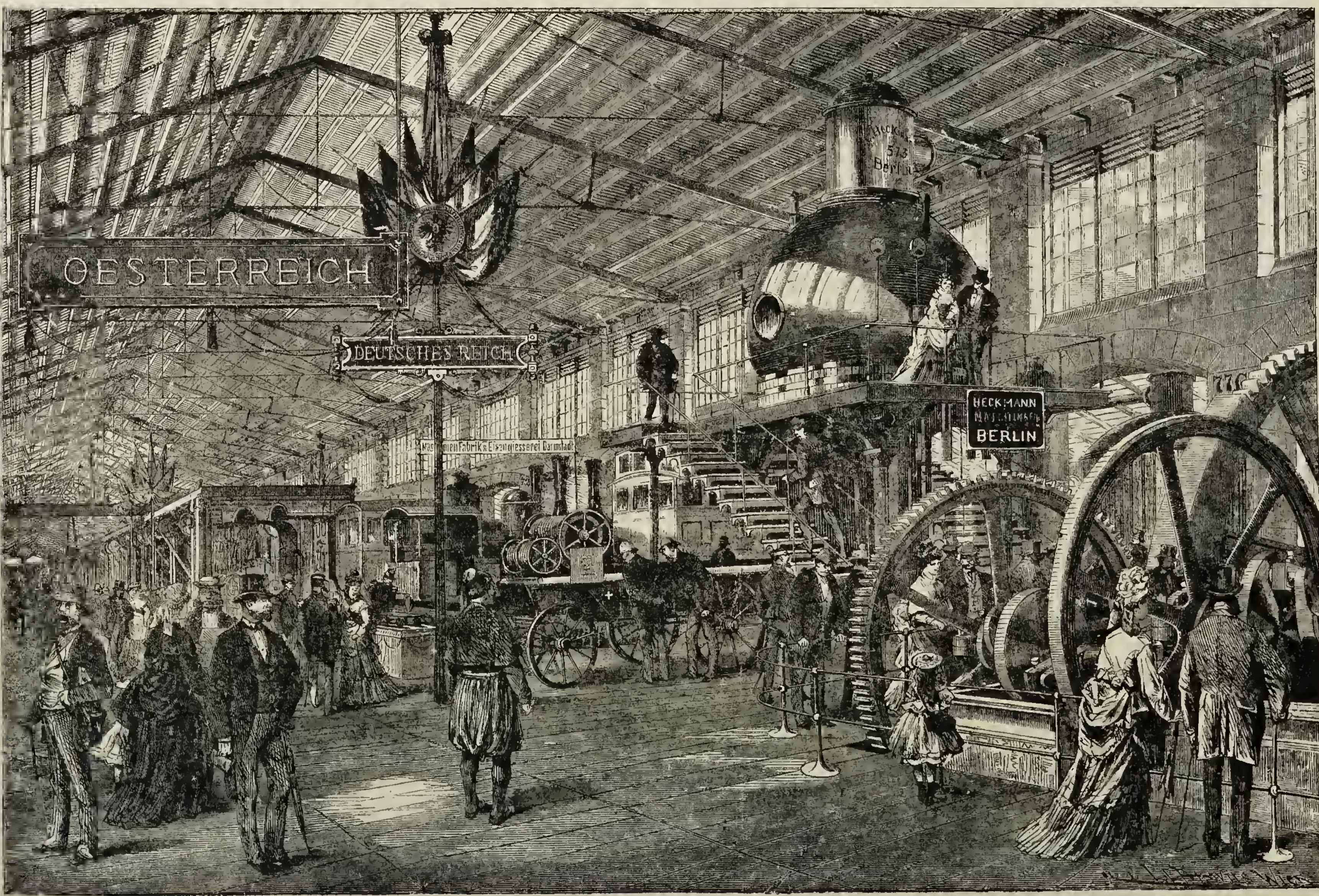
* Col. T. T. S. Laidley has furnished to the Army Ordnance Bureau a translation of a lecture upon the same subject by General Uchatius. (See Ordnance Notes, No. XL.)

Vienna Exhibition 1873. Machinery. etc.



American Photo-Lithographic Co. N.Y. (Osborne's Process)

Fig. 207.

pressed from the former, and solidifies last. This latter alloy, then, forms in the inside of the casting, and also enters the cracks which sometimes form in the outer wall.

This behavior in fusion of alloys rich in tin was also noticed in the numerous researches on alloys of copper and tin made by Alfred Riche, and published in the "*Annales de Chimie et de Physique*," tome 30. M. Riche noticed that all alloys of copper and tin, except those whose compositions correspond to the formulas $Sn\ Cu_3$ and $Sn\ Cu_5$, undergo a refusion at the moment of solidification. An alloy richer in tin is separated, so that different compounds are to be found at different points in the casting. When the alloy consists of tin and copper in the proportion of 1 to 5, this refusion occurs to but a slight extent, but when the composition is different it becomes a very serious matter. Even the property of the tin of oxidizing easily seems to exhibit itself in this case, as it diminishes the chemical affinity of the metals still further, and thereby assists their separation.

As a proof of the occurrence of these conditions in alloy, we may mention that rich bronze, of a very homogeneous character, is always found in the smaller parts of bronze castings; for example, in the cascabel or in the trunnions of a gun. This bronze contains about 8 per cent. of tin, while the body of the gun is penetrated by thin sheets of tin. An 8-inch tube was made at the Royal Imperial arsenal, for which 28,000 kilograms (61,600 pounds) of metal were employed at once. The greatest diameter of this casting was about 0.84 meter, and the proportion of tin at this part was 8 per cent. on the outside and 12 per cent. on the inside.

The reason why bronze with 8 per cent. of tin has not yet been employed for guns is that its wear is greater than even that of 10-per-cent. bronze. "Gun-metal" has long been employed because of its great tenacity and consequent safety, and also because it has the advantage of cheapness and ease in working. Its strength has satisfied the demand nearly up to the present time, and it has, therefore, been retained in the manufacture of field-pieces, in spite of its tendency to bulge and to burn out. Modern requirements, however, will no longer permit its application as formerly.

From an accompanying table of properties of types of gun-bronze, we find those of ordinary gun-bronze, as compared with Krupp's steel for guns, to be—

	Bronze.	Steel.
Tenacity	2,260 kilograms per square centimeter, (32,092 pounds per square inch.)	4,800 kilograms, (68,160 pounds.)
Elastic resistance	400 kilograms per square centimeter, (5,680 pounds per square inch.)	900 kilograms, (12,789 pounds.)
Extension when broken	15 per cent	21.4 per cent.
Hardness, (depth of indenture)	12.5 millimeters, ($\frac{1}{2}$ inch)	10.5 millimeters, (.42 inch.)

We see that the tenacity as well as the limit of elasticity of cast-steel is almost twice as great as that of ordinary bronze, which has even less ductility than steel. If the properties of bronze could not be further improved—wrought iron being unreliable as gun-metal—we would necessarily be compelled to accept steel. But, fortunately, new wants are generally supplied in time by the progress of science and art.

300. We may next consider a new modification of gun-bronze, which is much superior to ordinary gun-bronze, according to the annexed table of gun-metals, and for which General Von Uchatius has proposed the name "steel-bronze," on account of the resemblance of its properties to those of cast-steel.

If, instead of employing sand, we used iron chills of a corresponding thickness of material, the process of solidification takes place with such rapidity that the alloy rich in tin cannot separate, and the bronze becomes perfectly homogeneous.

The quality of this homogeneous bronze is given in the typical table of gun-metals under the head of "Chilled-bronze, natural."

The absolute strength rose to 3,050 kilograms, (43,310 pounds per square inch,) the elastic limit remained at 400 kilograms, the hardness (depth of indenture) at 12.5 millimeters, (.5 inch,) while the amount of stretch before breaking, or the ductility of the material, rose to 40 per cent. These improvements in the quality of bronze are a step forward in bronze-casting, but it is, nevertheless, not sufficient to satisfy modern requirements. A gun-barrel cast in this manner would not burst, for the ductility of the material at 40 per cent. is enormous, but it would not be capable of resisting the pressure of the gas; and, since the elasticity is not greater than with ordinary bronze, the gun-barrel would bulge out. The hardness also remained unchanged, and it is therefore not enough to cut the grooves in the sabots of the shot.

301. General Von Uchatius next tried to roll a piece of the chilled bronze cold. This could be done quite well, although considerable power was necessary. Not the slightest crack was produced, even when stretched to the amount of 100 per cent. of its original length. When the bronze had stretched 20 per cent., it attained the strength, hardness, and elasticity of steel, as can be seen from his table of gun-metals, under the heading of "Chilled bronze, rolled." The numbers are as follows:

The tenacity, 5,066 kilograms per square centimeter, (71,937 pounds per square inch.)

The elastic resistance, 1,700 kilograms per square centimeter, (24,140 pounds per square inch.)

The hardness, (depth of indenture,) 10.2 millimeters, (.41 inch.)

It is evident that if this characteristic of chilled bronze, of assuming the properties of steel when rolled, could be employed on the inner surface of gun-barrels, the process would be of great value. By examining the table of gun-metals, he remarks the peculiarity that all tough metals assume a much higher elasticity when they are stretched beyond their elastic limit.* For, when a substance is permanently changed by exterior forces, its molecules have been, at least partially, pushed be-

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* This fact was noted by the writer in 1873, immediately after returning from Vienna, and announced to the American Society of Civil Engineers in the following note, published in the Transactions, 1873:

AMERICAN SOCIETY OF CIVIL ENGINEERS.

A note on the resistance of materials, by Prof. Robert H. Thurston, member of the society, read at the regular meeting, November 19, 1873.

On the 13th ultimo an apparatus for determining the torsional resistance of materials, which I had designed for use in illustration of my course of instruction, and to which I had fitted an automatic recording-attachment, was exhibited to the National Academy of Science, at the late session held at this place, for the purpose of showing the peculiar adaptability of the machine for the determination and analysis of the action of physical and molecular forces in resisting stress, and to illustrate the bearing of experiments already made upon scientific investigations of molecular relations.

At the close of the meeting a test-piece of wrought iron was left in the machine, exposed to a strain which had passed the limit of elasticity, and with a distortion of 45°, the intention being to determine whether, as has been suspected by some writers and by many engineers, "viscosity" is a property of solids, whether a "flow of solids"* could occur under long-continued strain just equilibrating, when first applied, the resisting power of the material, or whether the "polarity" of Professor Henry is an absolutely unrelaxing force.

The metal was left under strain twenty-four hours, and had not then yielded in the slightest degree. This result, and the results of other similar experiments since made confirming it, indicate that metal strained far beyond the limit of elasticity, as above described, does not lose its power of resisting unintermitted static stress.

The important bearing of this fact upon the availability of iron, and of steel, which also behaves similarly, for use in constructions exposed to severe strains, is readily seen.

After noting the result obtained as stated, it was attempted to still further distort the test-piece, when the unexpected discovery was made that its resisting power was greater than when left the previous day, an increase of resistance being recorded amounting to about 25 per cent. of the maximum registered the preceding day, and approximating closely to the ultimate resistance of the material. Repeated experiments, continued up to the date of writing, confirm the following previously undemonstrated principle, that iron and steel, if strained beyond the limit of elasticity and left under the action of the distorting force which has been found just capable of equilibrating their power of resistance, gain resisting power to a degree which has a limit in amount, approximating closely, if not coinciding with, the ultimate resistance of the material, and which had a limit, as to time, in experiments hitherto made, of three or four days.

Releasing the piece entirely and again submitting it to the same force immediately does not produce this strengthening action.

There is some evidence, that is confirmed by theoretical dynamic principles, that the increase of strength noted is not accompanied by a change of resilience, but that the gain of resisting power is at the expense of a proportional amount of ductility.

The diagrams obtained during this research will be presented at a future time, when the investigation shall have been completed.

The interest and importance attaching to the discovery of the principles above enunciated, to our profession as well as to science, will, I hope, justify the presentation of this note.

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* Mon. H. Tresca: Sur l'Écoulement des Corps Solides. Paris, 1869-'72.

yond the limit of their stability, and have assumed new and more or less stable positions. The change in the positions of the molecules consists of a constant and a temporary part, which latter belongs to the elasticity of the new form. The material attains a new stable equilibrium of the molecules, but at the same time a greater elastic resistance.

In this fact we may also find the explanation of a phenomenon observed at several places. A bronze barrel which was not strong enough to resist its charge, and which, therefore, bulged out, still retained its form after long-continued use. It could even be weakened, by turning off on the outside, without losing its power of resisting charges. The natural chilled bronze has its limit of elasticity at 400 kilograms, (5,680 pounds per square inch,) and permits a stretch of 0.0004 of its length; while, if a permanent set of 0.00441 of its length is produced, its elastic limit becomes 1,600 kilograms (22,720 pounds per square inch) and its stretch within the elastic limit, 0.00192. The rolled chilled bronze attains its limit of elasticity at 1,700 kilograms, (24,140 pounds per square inch,) and has an elastic extension of 0.0017 of its length, while a permanent stretch of 0.00018 of its length raises the limit of elasticity to 2,400 kilograms (34,080 pounds per square inch) and its elastic extension to 0.00252.

This advantage is as great with steel, wrought iron, and, in general, all extensible metals, as may be seen from the table for gun-metals, but it has never before been taken advantage of for the production of guns.

302. The following principle was enunciated by General Von Uchatius as a theory of working a gun-barrel from a homogeneous, very ductile, and tough metal. It is based upon results obtained by precise measurements upon the properties of the metals:

I. The work performed by the pressure of the gases of the exploded powder, and destroying the fit of the shot by enlarging the bore, should be performed originally by mechanical means, and to a far greater extent than will be produced by the heaviest charge. By this means the elastic limit of the metal of the barrel is increased to such an extent that the smaller pressures of gas produced in discharging the gun have no effect.

II. The surface of the bore must be submitted to a process resembling rolling to such an extent as to give it the necessary hardness.

By this process of mechanical working of the casting the material is not overstrained, as has been frequently asserted. Its properties are not injured; on the contrary, as this extension goes on in the cold state, and not while warm, the molecules take new and stable positions, refining the metal. Its properties are, therefore, improved.

Drawn tubes, piano-wires, &c., are of similar nature, and have also been extended. They are, nevertheless, sound and reliable.

303. Before proceeding to the method of working on the casting, it was necessary to solve two very important problems, namely:

(*a.*) Which alloy of copper and tin is best suited for chilled casting?

(*b.*) How can the quality of the metal at the inside, or nearest the bore, be made to correspond to that of the alloy at the outside, so that the metal can be subjected to the process of rolling?

In order to determine the best quality of alloy, a small cast-iron chill was made, of 25 millimeters (1 inch) and 50 millimeters (2 inches) width in the clear, and 25 millimeters (1 inch) thickness of sides, into which the following alloys were cast:

12 per cent. bronze.
10 per cent. bronze.
8 per cent. bronze.
6 per cent. bronze.
10 per. cent. bronze, with 2 per cent. addition of zinc.
10 per cent. bronze, with 1 per cent. addition of zinc.
8.5 per cent. bronze, with ½ per cent. addition of zinc.

The last of these alloys is that which the French firm of Lavissière exhibited at the Vienna Universal Exposition in the year 1873, and which attracted the attention of professional men by its uniform and homogeneous appearance and by its peculiarly excellent properties.

Two rods were cut from each of these castings, and these were rolled out until they acquired the hardness of steel. It became evident, during this process, that the 12 per cent. bronze could not bear rolling, and therefore the tests were limited to the remaining alloys.

It was found necessary to continue the rolling of the rods in order to reach the hardness of steel; with the—

10 per cent. bronze, to an elongation of 20 per cent.;
8 per cent. bronze, to an elongation of 30 per cent.;
6 per cent. bronze, to an elongation of 50 per cent.;

with the—

10 per cent. bronze and 2 per cent. zinc, to an elongation of 10 per cent.;
10 per cent. bronze and 1 per cent. zinc, to an elongation of 15 per cent.;
8.5 per cent. bronze and ½ per cent. zinc, to an elongation of 20 per cent.;

The results of the tests made can be seen from the following table:

Alloys.	Tensile strength.		Elastic limit.		Elongation within the elastic limit in 0.00001.	Set in per cent. of length.
	Pounds per square inch.	Kilograms per square centimeter.	Pounds per square inch.	Kilograms per square centimeter.		
10 per cent. bronze	71,937	5,066	24,140	1,700	174	1.5
8 per cent. bronze	73,840	5,200	19,880	1,400	140	2.5
6 per cent. bronze	77,532	5,460	18,460	1,300	128	3.5
10 per cent. bronze and 2 per cent. zinc	42,884	3,020	8,520	600	89	0.5
10 per cent. bronze and 1 per cent. zinc	59,214	4,170	14,200	1,000	120	0.7
8.5 per cent. bronze and ½ per cent. zinc	53,960	3,800	21,300	1,500	157	1.7

These tests showed that, in general, the 10 per cent. as well as the 8 per cent. and 6 per cent. bronzes are capable of being employed in the new method of making gun-barrels, while the addition of zinc is of no use whatever, but, on the contrary, decreases its value to no inconsiderable degree.

The 8 per cent. bronze was judged to be the best for large castings, and this one has, therefore, been taken as the basis for steel-bronze.

304. A number of trials were made to determine what method of casting and cooling would make the inner layers of the casting homogeneous, and which would have the necessary toughness for standing the treatment to which they were to be subjected later. These trials required much time and patience, and were so extensive that they cannot be enumerated here. The result of all these trials, that is, the method of casting which fulfilled the object in question, and which was, therefore, adopted, cannot be communicated, as it is kept a secret by General Von Uchatius.

Simultaneously with these trials, those castings whose quality was shown to be good, by the appearance of the fracture, were subjected to the mechanical treatment. A hydraulic press was employed for this purpose, its capacity being 100,000 kilograms, (220,000 pounds.)

305. The following is a short sketch of the main features of the method which has been employed for making gun-barrels since September, 1873:

At the beginning of the year 1874 a work was published entitled "*Esperienze mechaniche sulla resistenza dei principalia metalli da bocche da fuaco, di G. Rosset*," &c. This work produced the impression, in many minds, that the experiments of General Von Uchatius were in imitation of those there described. This is, however, clearly disproved by the fact that these trials were already begun at the end of the year 1872, and that the improved method of casting had been determined upon in September, 1873. The priority of invention of this method of casting and of the following mechanical treatment is, therefore, undoubtedly to be attributed to General Von Uchatius.

The castings were 260 millimeters (10.4 inches) thick, 300 millimeters (12 inches) long, having a bore of 80 millimeters (3.2 inches) diameter. They were conical and turned down at one end to 180 millimeters (7.2 inches) diameter. They were then placed vertically under the plunger of a hydraulic press, which was then driven through it. The surface of the press-plunger was of well-hardened steel, and was a slightly-tapering cone, thus increasing the diameter gradually. But, since the resistance increased with the enlargement of the barrel, the difference between the diameter of the plunger and that of the last-formed barrel must decrease gradually. Six plungers were employed in succession, of which the first increased the bore by 2 millimeters (.08 inches) and the last by ½ millimeter (.02 inch).

The original diameter of the bore, 80 millimeters, (3.2 inches,) was thus increased to its normal size of 87 millimeters, (3.88 inches;) that is, the increase amounted to 7 millimeters, (.28 inch,) or 8.75 per cent., while the exterior diameter of the casting was increased by 2 per cent. The surface of the bore which was thus produced had a hardness, when measured by indentation, of 10.5 millimeters, (.42 inch,) or equal to that of gun-steel ; it was as smooth as a mirror, and only needed rifling. It was further remarked that the same result as to hardness was produced at the end which was weakened by turning down, which would seem to indicate that the outer layers of guns do not come into play at all when firing.

306. We have remarked before that the principal advantage of the new method of manufacturing guns was to be found in the fact that the barrels may be cast of a very tough and homogeneous material. They are then bored out a little smaller than the required size, and brought to gauge by driving in steel cones which increase successively in diameter.

The concentric layers of the cylinder are all strained beyond their former limit of elasticity by the forcing into them of these plungers, and they are thus given a greater elasticity. At the instant that the plunger is passing through, the layers are all strained beyond their original elastic limit, and up to a new limit of elasticity. After the plunger has passed through, the inner layers not only return to their new positions of equilibrium, but they are pressed back even further by compression due to exterior layers. The diameter of the bore is decreased, after the last plunger has passed through, from 87 millimeters (3.48 inches) to 86.652 millimeters, (3.47 inches,) or by about 0.004.

The whole barrel is also rolled, especially the inner layers, as an increase in length takes place, as well as an increase in diameter. With a field-piece, this elongation amounts to from 10 to 12 millimeters, (.4 to .48 inches,) or about 6 per cent., the elasticity, strength, and hardness being thus still further increased. The ductility of the inner layers especially is decreased by this rolling process ; but it is an advantage to exchange some ductility for other properties, with a material like homogeneous bronze, which has an extensibility of 50 or 60 per cent.

In firing, the bore of the gun is suddenly slightly enlarged. As long as this enlargement of the bore does not exceed 0.004 of the diameter, the form must remain unchanged, like a spring which has been strained within its elastic limit. Only when the shock of the discharge increased the diameter beyond this amount, would the limit of elasticity of the barrel be passed, and a permanent increase of the bore take place. But since the bore can only be enlarged to the extent of 0.004 of its diameter, by a force equal to the pressure exerted by the last plunger—that is, 2,400 atmospheres—it may confidently be expected that the barrels produced in this manner will come up to the requirements, particularly as the tension of the gases at the discharge of a field-piece only amount to two-thirds of that pressure.

307. The material of the first two experimental barrels of steel-bronze had the following properties:

Properties of steel-bronze.	Test-barrel No. 1, near the—		Test-barrel No. 2, near the—	
	Bore.	Exterior surface.	Bore.	Exterior surface.
Tensile strength per 1 square centimeter, in kilograms	4, 250	3, 320	4, 250	3, 320
Tensile strength per 1 square inch, in pounds	60, 350	47, 144	60, 350	47, 144
Limit of elasticity per 1 square centimeter, in kilograms	1, 100	500	1, 100	700
Limit of elasticity per 1 square inch, in pounds	15, 620	7, 100	15, 620	9, 940
Stretch, ultimate, in per cent. of length	16. 5	50	16. 5	50
Stretch, elastic, in per cent. of length	0. 306	0. 060	0. 306	0. 060
Section at the point of rupture, which was originally taken = 1. 00	0. 56	0. 50	0. 56	0. 50
Hardness, depth of indenture, in millimeters	10. 6	12	10. 6	12
Hardness, depth of indenture, in inches	. 42	. 48	. 42	. 48

Both barrels were subjected to tests by firing.

The object of the tests with the steel-bronze barrel No. 1 was to ascertain to what extent the theoretical ideas above enunciated would apply to this kind of gun-barrel.

These tests were made on the "Simminger Haide," from 40 to 50 shots being fired daily, two shots with the diminished charge of 1 kilogram (2.2 pounds) and 238 shots with the normal charge of 1.5 kilograms, (3.3 pounds.) The hollow and double walled projecticles, 2½ diameters in length, had four copper packing-rings, and the powder used for the charge was large-grained powder from the factory at Stein, the size of the grains being from 6 millimeters to 10 millimeters, (.24 inch to .4 inch;) the density was 1.605.

The truth of the theory enunciated by General Von Uchatius as to the construction of gun-barrels was demonstrated by the fact that the barrel showed no signs of either a widening of the bore or any other flaw after these tests.

The test-barrel No. 2 was tried on the "Steinfelder Haide." The object of these tests was to determine the decrease in precision of firing consequent upon the firing a great number of shots with the charge of 1.5 kilograms, (3.3 pounds,) and with double-walled projectiles 2½ diameters in length, weighing 6½ kilograms, (14 pounds.) The velocity attained with this charge was measured as 1,480 feet. On the whole, 2,130 solid shot were fired and twenty shells were thrown.

The subsequent examination of the barrel showed the chamber to be altogether unchanged. The widening which was perceptible—about 0.1 millimeter (0.004 inch)—was due to burning out and to mechanical wear. The lands and grooves of the barrel were worn considerably, after this great number of discharges, by mechanical wear and by burning out, but from the mouth to the vicinity of the trunnions the lands were left quite sharp, and consequently were capable of seizing the projectile with perfect accuracy, giving its axis the necessary stability in the barrel.

After 2,100 discharges, a well-adjusted, double-walled projectile was purposely made to burst in the gun, in order to determine the amount of damage thus produced and its effect upon the accuracy of fit of the shot. The following series of 25 shots did not show any loss of accuracy, although the grooves and lands were badly damaged, for the latter appeared to be crushed down and the metal squeezed into the grooves. Yet 100 per cent. successful shots were made on a range of 1,500 meters, or 2,000 paces, the target being 3.6 meters (10 feet) in height, and the mean breadth being only 62 centimeters, (24 inches.) A more satisfactory result could not be desired.

It should also be stated that the wedge closing of the breech, and made of forged bronze, as well as the copper packing-ring, gave perfect satisfaction, and did not seem nearly as liable to burning out as steel packing.

308. It remained only to determine whether the same quality of bronze can be made for a great number of barrels. This being the case, we would expect that steel-bronze barrels would come into general use, in place of cast-steel barrels with rings shrunk upon them.

The pecuniary advantages attending the adoption of steel-bronze barrels would be considerable. A cast-steel barrel, with built-up rings, costs, after deducting the value of the waste metal, 1,500 florins, ($750.) A steel-bronze barrel, under the same conditions, costs 350 florins, ($175.)

The workshops of the Royal Imperial Arsenal could furnish annually steel barrels, built up with rings, 150; steel-bronze barrels, 1,000.

309. Experiment indicates how the properties of the tough metals may be improved by stretching beyond their elastic limit, either by loading-rods, or by forcing conical plungers through the cast cylinders while cold. The density, and, to a great extent, the elasticity, are increased considerably by such treatment.

The metals are generally weakest when cast, stronger when hammered or rolled, but strongest when drawn.

It will be seen that this method of working castings applies advantageously to the production of steel gun-barrels. Steel, having at once an elastic limit of 2,000 kilograms per square centimeter, (28,400 pounds per square inch,) and a ductility of 20 per cent., cannot be produced by any hardening process or method of manufacture, but only by stretching in the cold state.

The barrel of a heavy field-piece treated similarly to the tube of very soft Neuberg steel would be even better than a ringed steel barrel, and just as good as a steel-bronze barrel. The cross-section of such a barrel shows the same constitution as one of steel-bronze.

The quality of the material in the concentric layers changes continually in such a manner that its density, elasticity, and hardness increase continually as the surface of the bore is approached in exactly the manner required to resist the shock of discharge. At Creusot it has been tried, in vain, to produce this result by hardening the barrels from within outward, the propriety of the above constitution being recognized. This result may be attained approximately with guns by shrinking softer rings upon the hard center. Sudden changes take place in this case, and the separation of the core from the hoops must be allowed for.

With larger barrels, where rings must necessarily be employed, these need only be stretched, when cold, by conical plungers driven through them, which will give them such a degree of elasticity that they may be shrunk on with a pressure of 2,400 atmospheres, 36,000 pounds, without passing their limit of elasticity.

310. The steel-bronze barrels will, according to General Uchatius, always be better than those of steel, for the following reasons:

1. On account of the quadruple price of the steel, and because old steel-bronze barrels can always be remelted.

2. On account of the time required in manufacturing, which with steel is six or seven times as long as that needed with steel-bronze. In order to produce a cast-steel barrel fitted with rings, the inner tube is first cast. It is then heated and worked under the steam-hammer; it is then bored, and finally the rings are shrunk upon it. For this purpose are needed, not only very costly plant, but also skilful, experienced, and very reliable workmen. The steel-bronze barrels are simply cast, then bored and pressed, and finally drawn; all of which manipulations are very simple.

3. On account of the greater rapidity of destruction of the steel by atmospheric influences. The destructive effect of oxidation rapidly penetrates to the interior with steel, while steel-bronze merely receives a superficial layer of verdigris, which does not penetrate.

4. Because steel barrels are not as safe for the gun's crew as steel-bronze barrels, of which the exterior layers are so tough that they must be stretched 50 per cent. before fracture.

Captain Volkmar, of the Austrian army, who has studied the process and experimented with the material under the direction of General Von Uchatius, is very enthusiastic in his statement of its value.

These new modifications of the most generally useful metals, iron and bronze, are well worthy of extended experimental examination.

311. There is no apparent reason why the same process should not similarly benefit the "low steels" which are coming into such general use.

These peculiar products are of interest, not only as valuable commercially, but as exhibiting a singular, and as yet a mysterious, molecular change which results from simple compression.

312. UNDERHILL'S ANGULAR BELT, seen in the engraving of the Pickering engine; MASON'S FRICTION-CLUTCH PULLEYS, which are now well known in the United States, where the writer has known their value by experience and by an acquaintance of ten or fifteen years; and several other important exhibits, attracted deserved attention and secured recognition by the jury of Group XIII.

313. In the Austrian section, the HYDRAULIC FORGINGS OF Mr. J.

HASWELL were exhibited by the K. K. Priv. Staats-Eisenbahn-Gesellschaft of Vienna, of whose workshops Mr. Haswell is manager.

These forgings are produced in properly-shaped molds or dies, by the pressure of powerful hydraulic presses upon the iron, which is first raised to a welding-heat. The metal is quite easily worked by this method if the heating is well done, and fills the molds as perfectly as if molten. The method is said to be comparatively inexpensive, and the forgings shown at Vienna as the product were of excellent character. Some were quite intricate in form.

The press used for this work had a power of between 800 and 1,000 tons. The water-pressure was stated at about three tons per square inch.

A new press then in course of construction was to have a "ram" two feet in diameter, and to work with the same water-pressure, giving a total pressure of about 1,500 tons.

The cylinder was to be of cast iron lined with steel. In this press a neat device causes the water discharged from the chamber of the press to enter a storage-reservoir, whence it is again taken to fill the chamber before the pressure is put upon the die, and while the ram is settling down to its work. A draw-back cylinder is mounted above the main cylinder, for the purpose of raising the ram from the mold. Mr. Haswell thus makes eccentrics for his locomotives, and frequently both forward and backing eccentrics are made in a single piece. He makes also pistons, axle-boxes, and cranks in the same way; and it will probably be found the best method of construction of many details which have usually been made in cast metal.

Hydraulic forging was not invented by Mr. Haswell, but he seems to have been the first to make this method a practical success. He not only uses his press in doing work usually made by ordinary forging or by the drop-press, but also such as is usually accomplished by the steam-hammer, as in "cogging" steel ingots.

314. Wheel-centers made under this press were among the heaviest pieces shown, and were fine pieces of work. In Austria, and throughout Europe, cast-iron wheels are never seen.

The finest wheels for locomotives, forged in the ordinary way, were shown by Déflassieux, Frères & Peillon, of Rive-de-Gier, in the French section.

315. Three STEAM-CRANES were supplied to the British department by the Messrs. APPLEBY BROS., which did excellent work during the installation of the exhibits, and they are worthy of mention for their compact, neat, and mechanical design and their excellent workmanship. These cranes (Fig. 208) were like those used by the British commissions in Paris and London. They were of three, five, and seven tons capacity, respectively. They differed only in their proportions. The bed-piece is in one piece. The main column is made of wrought iron. The top carries a spur-wheel, which is so attached that it may be made fast or

loosened, as required, while operating the crane. The truck carries a light iron floor, in the middle of which is an opening large enough to take in this gear. On the border of this circular opening is a track on which run the friction-wheels, carrying the frame of the crane and its appurtenances. The central column steadies the whole and keeps these rollers on the track as they revolve about it. These rollers, or friction-wheels, are three in number—two under the heel of the jib and one under the steam boiler, which is on the opposite side of the central post. The boiler has a cylindrical shell, with fire-box and flat upper head, and stands vertically. It contains a set of small flues, the makers considering it better to use a form which is not especially liable to give trouble where bad water is used than to adopt the tubular boiler, although the latter is superior in economy. The engines are carried on a pair of vertical A-frames, mounted between the crane jib and the boiler. They are two in number, and drive one crank-shaft, each being attached to a crank-pin at its own end of the shaft, and these cranks being at right angles. Thus the whole apparatus is pretty nearly counterbalanced when the crane is moderately loaded. Between the frames are properly-arranged trains of gearing by which the jib can be raised or depressed, to give it less or greater reach, and by means of which the tackle is overhauled in raising the load, and by the use of still another of which sets of gearing the truck may be driven on the track, carrying the crane and its load.

The first motion is secured by means of a fast-and-loose bevel-gear on the crank-shaft, which acts, through a worm-shaft and its gears, upon the barrel carrying the chain attached to links leading to the head of the jib. The second motion is obtained in the usual way, the engines driving the chain-barrel through the ordinary arrangement of intermediate transmitting gearing. A change of speeds is provided for light and for heavy loads.

The traversing-motion by which the crane is turned about the wrought iron column as a center is similarly attached, acting upon the large spur-gear first mentioned. In this motion the connection is made by friction-clutches, to prevent injury by suddenly stopping.

The traversing and hoisting gearing can be made to work together, the load rising or falling while the crane is rotating on the truck.

The exhibitors stated that, with light loads and high speeds, they can transfer and hoist one load per minute. They state that one of these cranes was employed to transfer from the cars to their place in machinery-hall a load of machinery which comprised all of the parts of the large oscillating marine paddle-wheel engine exhibited by the *Société Cockerill* in the Belgian section, and that this was done in six hours' work, including also the drawing of the loaded cars into position by the crane itself, and carrying them away as fast as unloaded.

The great blowing-engine shown by the same firm was similarly erected in five hours.

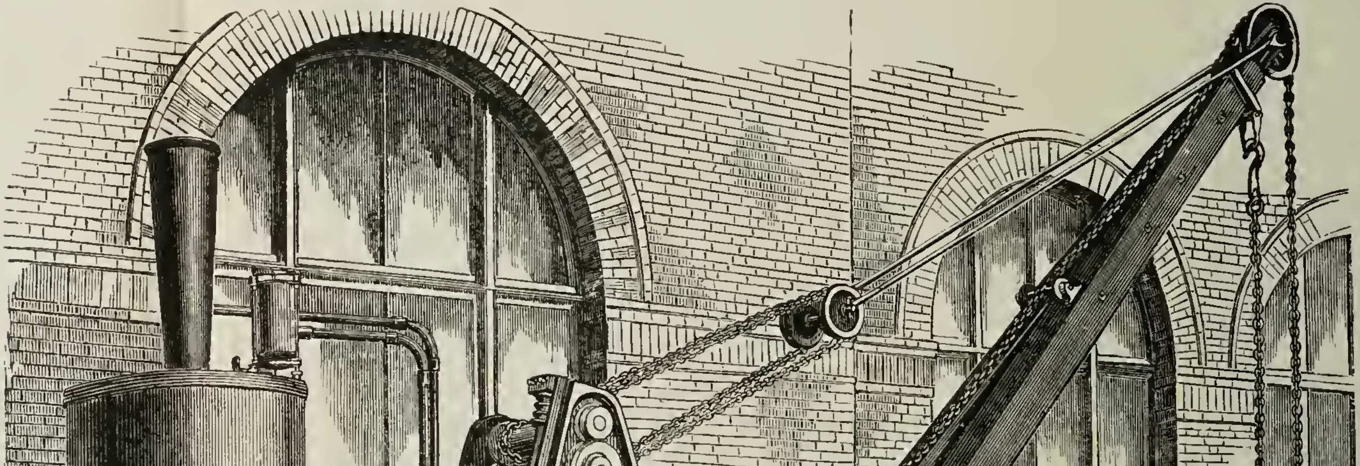

Fig. 208.—Appleby's steam-crane.

These cranes were thus found very useful at the installation and the removal of the machinery and of heavy exhibits in other departments.

These were among the best of the miscellaneous class of machinery exhibited in the British section. They were well planned in general and in detail. They were excellently proportioned, well made, and were destitute of every attempt at useless finish or ornament. They were as light as was consistent with their necessarily substantial character. The combination of motions just indicated was extremely useful, and neither element of the combination seemed to interfere with the operation of the others. The jib was swiveled, in its vertical motion, about a pair of pins at the feet of its two legs, and this arrangement permitted a broad base of support laterally, rendering the jib stiff against surges toward either side in swinging the load or in traversing.

Messrs. J. H. WILSON & Co., of Liverpool, also exhibited a design, differing in detail, but very similar, as a whole, to that of Messrs. Appleby. The same motions were all secured, and in the same general way. The boiler was even simpler in form, but the framing and the arrangement of the gearing was perhaps somewhat less well-considered. The machine did excellent work.

316. The following engravings exhibit a neat little device shown in the United States section, which may properly be described here. This is the HORTON LATHE-CHUCK AND JAW.

Fig. 209 gives a view of the chuck complete and in parts. The main feature is that of inclosing the circular wrought-iron rack in a deep groove or recess in the back-plate, and then turning the center-faces of back and front plates true. When bolted together this makes a perfectly-tight casing for the gearing, so that no dirt or chips can possibly get into them to clog or injure the chuck. When the rack is taken out, this makes an excellent independent jaw-chuck. It thus virtually makes two chucks combined in one. The jaws are solid, forged of one piece of the best wrought iron, and case-hardened with animal charcoal.

Fig. 210 represents the "inside chuck." This chuck is quite well known as the one used on the Brown & Sharpe universal milling-machine.

Fig. 211 gives a view of the form of all chucks over 12 inches in diameter. These are made in one casting, with the exception of a circular ring-cap, which incloses the rack in the same manner as in the smaller sizes. This allows slots to be made entirely through the body of the chuck, and thus makes it very convenient to bolt work upon, if required, or to use it as a face-plate with the lathe-dog.

The center hub is simply a straight piece planed off on three sides and fitted into the center of the chuck. If a larger hole is wanted in the chuck, this hub can be quickly taken out.

Fig. 212 presents the new jaw for the lathe-chuck. The object of this improvement is to make the jaws of a chuck so that they may be ground perfectly true both on face and bite, and thus be made more reliable in holding the work.

It is a common experience in case-hardening jaws that the form changes more or less, so that it is almost impossible, without grinding, to hold work perfectly true. To overcome this difficulty, a raised seat A A, is introduced on the face of the jaw, on which the work rests while turning. There is a groove, or recess, formed in the corner of the bite and face of the jaw. This groove admits of the use of the emery-wheel for grinding off the raised parts A A, so that work coming to a sharp corner will rest upon the ground seat A and the bite of the jaw only, and assume a perfectly true position, an equal pressure being then exerted.

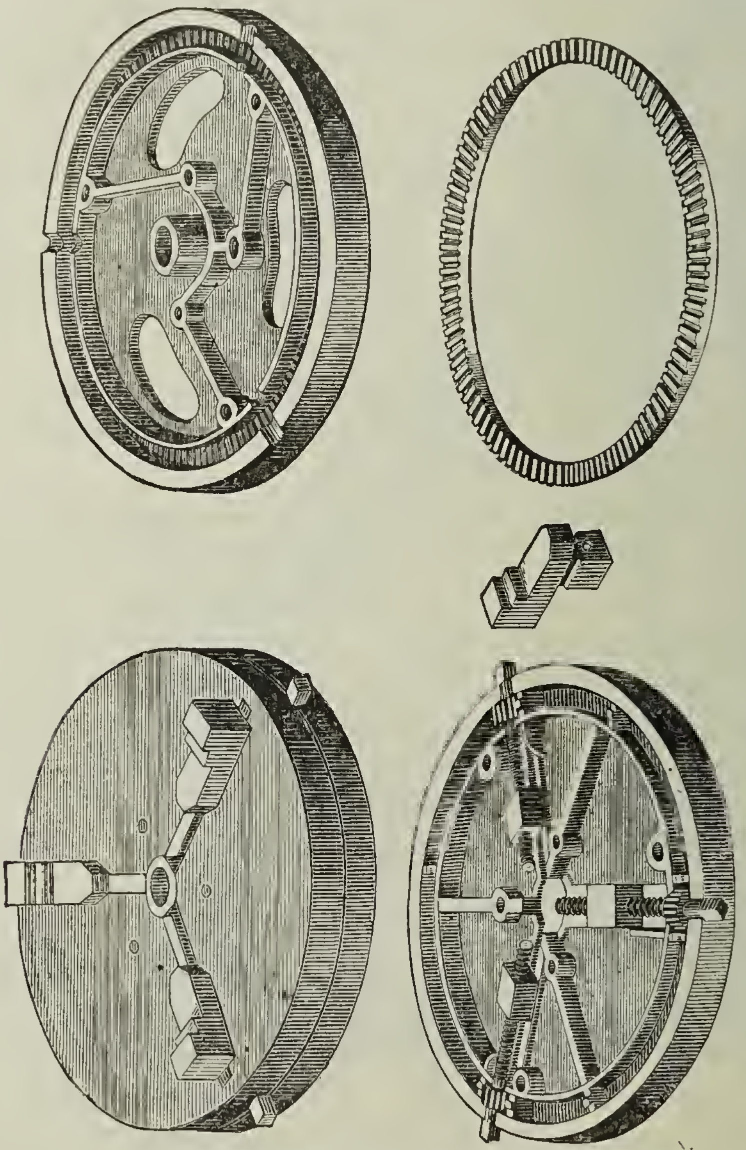

FIG. 209.—Horton's lathe-chuck.

Another advantage of the groove is that a grinding wheel without a perfect corner will do its work accurately, as the wheel projects beyond the raised part in the recess formed by the groove, and thus grinds the seat perfectly true.

317. GERMAN OPINION OF AMERICAN TOOLS.—Dr. E. Hartig, a mem-

ber of the jury, and professor at the Royal Saxon "*Polytechnikum*," at Dresden, in his report, published since the above section of this report was written, remarks: "If we accept the expression 'machine-tools,' according to modern usage, as including not only machines for dressing and working metals, but also the machines for dressing and working wood, which have of late become very numerous and have come into extended use, and if to these we add the machines for dressing stone, we will then include that group of machines whose representation at the Vienna Exhibition was the most successful in every respect. None of the numerous divisions of this class was wholly without representation; no one of the countries that manufacture them was unrepresented. It is surprising that the machine-tool manufacturers of the United States were represented in a much greater number than upon any former universal exhibition, their exhibits being of unquestionable originality, and their value being made evident to every attentive visitor by the absence among

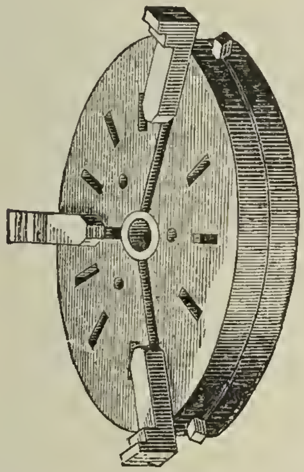

FIG. 210.—Horton's lathe-chuck.

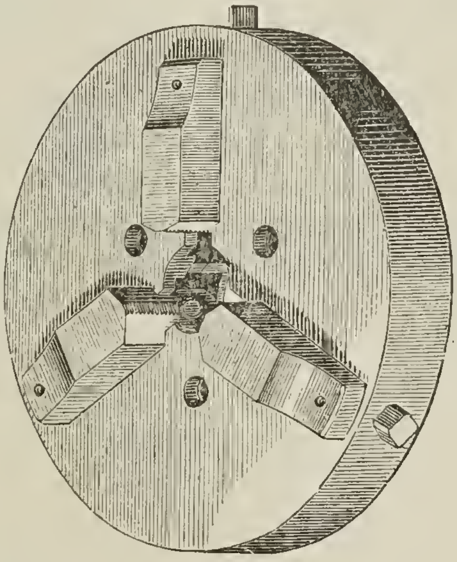

FIG. 211.—Horton's lathe-chuck.

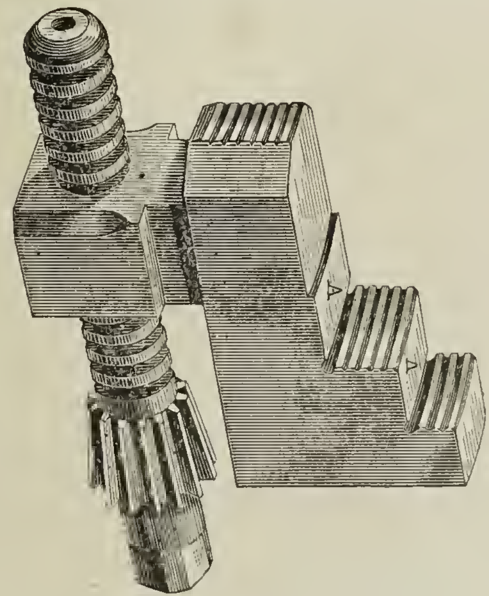

FIG. 212.—Horton's lathe-chuck jaw.

them of objects of inferior value. A true *élite* of reliable inventors and manufacturers: William Sellers, the originator of many unsurpassed designs; and Thomas Hall, the inventor of the handiest vise; B. C. Tilghman, the sand-etcher; and the Mowry Axle and Machine Company, who fastened the iron tires upon the wooden wagon-wheels without the use of heat! In considering this variety of triumphs of invention, the question naturally suggested itself anew, what influence is to be ascribed to the conception of the 'inventors' property,' when greatly refined and sharpened by an effective protection by patent-laws? A question which has found deliberate consideration and answer, in the course of the Exposition, by the International Patent Congress."

CHAPTER XII.

GENERAL REVIEW.

SCOPE OF THE REPORT: UNDESCRIBED EXHIBITS: TECHNICAL EDUCATIONAL EXHIBITS: NECESSITY OF STUDYING THE MANUFACTORIES OF EUROPE: BRITISH WORKINGMEN AS VISITORS TO VIENNA; AMERICAN MECHANICS AT VIENNA.

318. It has been the general intention of the writer in this report to review briefly only such machines and exhibits as came directly under notice while acting officially as a member of the International Jury, and such special exhibits as experience may have particularly qualified him to criticise.

There were a large number of exhibits at Vienna which were of great interest, not only to every mechanic, but to every intelligent person who recognizes the extent to which all progress in civilization, including intellectual and even moral advancement, is dependent upon the improvement of the materials and processes of the industrial arts.

The magnificent collections of Krupp, the proprietor of the immense iron-works at Essen, Prussia, the beautifully-graded steels and the splendidly-finished machinery shown by the Messrs. Schneider, of Creñsot, France, the noble show of heavy machinery exhibited in the Belgian section by the "*Société Cockerill*," of Seraing, the immense display of brass bronze and of other alloys and metals of Lavissiere, were each worthy of long and careful study.

319. TECHNICAL EDUCATIONAL EXHIBITS.—The writer, as an educator by position, although a "practical" man and an engineer by profession, was naturally much interested in the educational department of the *Austellung*, which may be looked upon as the illustration of the system of machinery by which we are to-day endeavoring to aid the advance of the more purely intellectual part of the work of civilization. The collections in this department were not as extensive as they should have been or as they were expected to be. The ordinary and standard apparatus which are everywhere used in higher schools and colleges, text-books in every branch of study for all grades and in every language, maps and charts, the familiar forms of physical and chemical apparatus, were all illustrated with some few novelties, but with rare examples of strikingly interesting innovations or improvements. The school apparatus and furniture from the United States, our American text-books, the French illustrative apparatus for very young pupils, the apparatus exhibited by London and Paris makers of philosophical instruments, were all attractive and exceedingly interesting to all who appreciate the public as well as

private benefits which follow the adoption of effective and truly practical methods of education. The German exhibits of apparatus for technical instruction were exceptionally interesting, both as constructions and as illustrations of German methods. Models exhibiting cinematic combinations, the various kinds of gearing, elements of machines, modes of transmission of power, models of typical forms of important machines, and other models illustrating processes of metallurgy and engineering were shown in great variety. Supplied with such apparatus, our American technical schools would, with their advantages of excellence of material in their classes, probably excel any schools, even of Germany, in the efficiency of the education which they would confer upon their students. A few of our professedly technical schools are already nearly as well provided with this kind of *material* as are the German, and one or two are even superior to all of the continental schools, with perhaps one or two exceptions, in this particular. It will probably not be long before we may expect to find ourselves in a position to offer to our young men all the advantages at home which they now seek abroad, and, in addition, some which can only be had in a country like our own and among a people like ours.

320. The engineer who attends the *Welt-Austellung* soon finds that, to learn thoroughly the lesson which he has come to study, he must pursue his investigations at a distance from, as well as within, the Exhibition limits. He finds there a splendid exhibit of machinery and of manufactured products; but to see the processes and the methods by which these products are created, he must visit the establishments which have contributed them. The writer, therefore, at the earliest possible moment, after the most important work was done, left Vienna to spend the remaining portion of available time in visiting some of the most successful or most interesting of those establishments in various parts of Europe, and also, where possible, to see something of that system of technical schools which has done so much for Germany.

321. While still at Vienna, a party of thirty-four English working-men arrived to inspect the Exhibition, and to report to the British "Society for the Promotion of Scientific Industry" the results of their examination of the several departments with which they were familiar. These reporters were selected by competition from among 320 applicants. They were working-men actually engaged earning their living by working at the trades which they were severally chosen to represent. These men were very intelligent and evidently well capable of doing the work assigned them in a creditable manner, and their reports will probably prove most valuable.

While laboring under the disadvantage of a lack of opportunity for obtaining the superior education of the Germans, and while having no such inducement to exercise that native inventive talent which he undoubtedly possesses in hardly a less degree than the American, and while involved in those sad quarrels which are a natural consequence of a misapprehension, by both masters and men, of those laws of political economy which control the relations between capital and labor, the English mechanic holds a position which commands the highest respect; and it may well be a cause of pride that we, who are closely competing with him, are his nearest relatives.

322. Other nations have, like the United States and Great Britain, sent corps of observation to Vienna, in which are included some of their most skilful artisans, and it may be fully expected that this enlightened policy will produce most valuable results. No nation, however, has as many representatives from among the class of "practical artisans" as the United States. Large numbers of our most intelligent and most experienced mechanics visited Vienna* to see for themselves what Europe is producing that is worthy of imitation. All were, probably, in some degree disappointed in their expectations of finding a large proportion of novelties, yet probably none came home feeling that the time and money which they had expended were lost.

From the Germans they learned the value of a practical mental and scientific training, and saw what it has done for a nation that cannot be termed a nation of mechanics. They learned also how well the Teutonic nations have developed this kind of education, and how much we, and still more the British, have been left behind in that great field of culture. They learned from the French that we do not excel in the combination of the useful with the ornamental, or in the exhibition of good taste in general work, or in the manufacture of those delicate kinds of apparatus and those marvellously perfect constructions which have become the ordinary tools of scientific work. From the British they learned to admire that simplicity of form and that substantial construction which distinguish the mechanical works of that nation to a degree that we may well hope at some future time to imitate, though perhaps hardly to excel. They learned, finally, that, while we may feel proud of the position already attained, we have still ample opportunity to improve in many ways.

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* See Scientific American, 1873; correspondence.

REPORT

ON

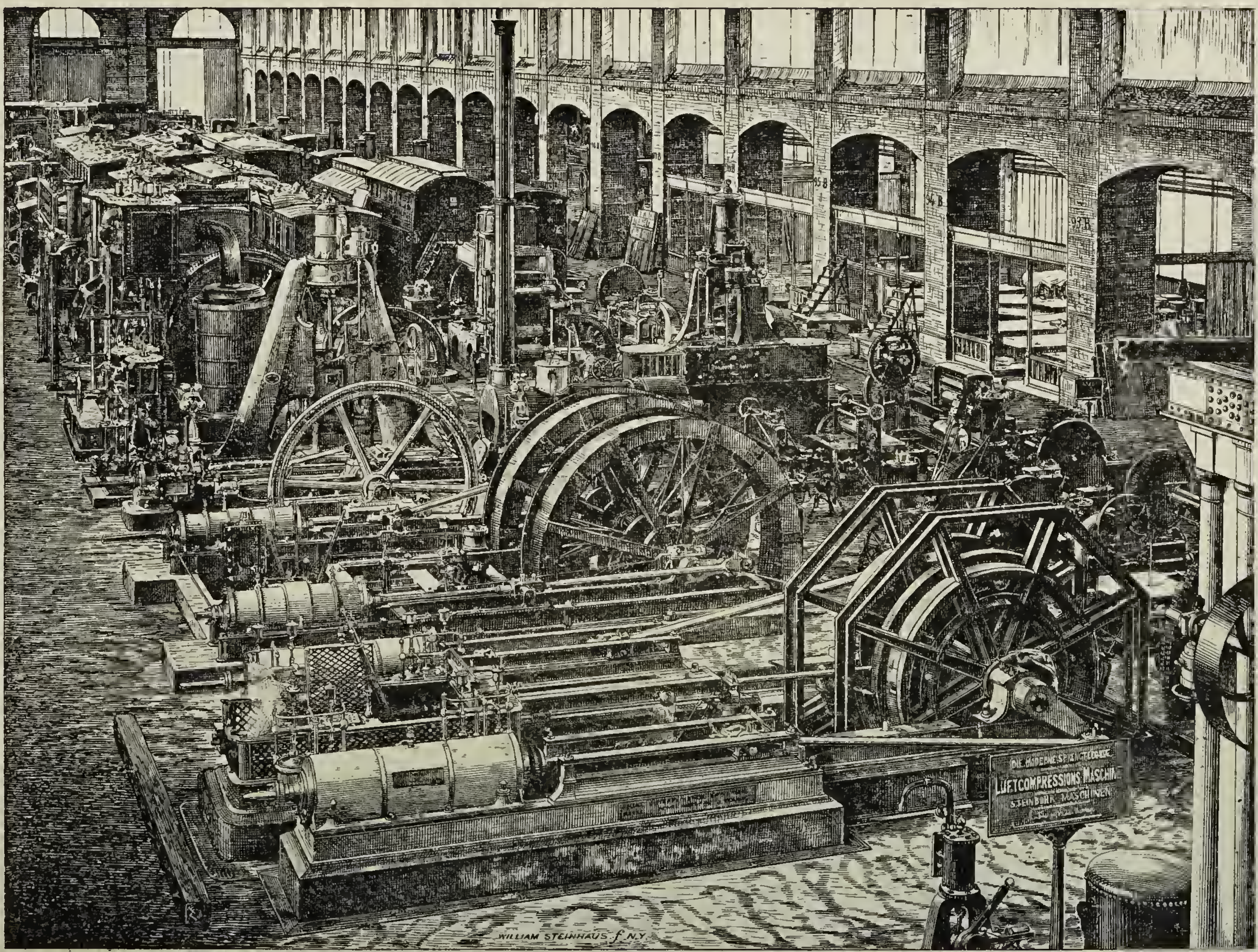
MACHINERY AND MANUFACTURES.

PART II.

THE MANUFACTURING DISTRICTS OF EUROPE.

Vienna Exhibition 1873.

Machinery etc.



American Photo-Lithographic Co. N.Y. (Osborne's Process)

Fig. 212

EUROPEAN MANUFACTURING DISTRICTS.

CHAPTER I.

SWITZERLAND AND HER MANUFACTURES.

INFLUENCES AFFECTING SWISS INDUSTRIES; COTTON-MANUFACTURES—THEIR DISTRIBUTION AND EXTENT; POWER-LOOM WEAVING; DYEING AND PRINTING; EMBROIDERY; SILK-MANUFACTURES—THEIR DISTRIBUTION; WATCH AND CLOCK MANUFACTURING; WOOLEN MANUFACTURES; LINEN-INDUSTRY; STRAW-BRAIDING; MANUFACTURES OF MACHINERY; IRON AND OTHER MANUFACTURES.

323. Immediately after the conclusion of the work of the International Jury, the writer left Vienna to visit the more important European manufacturing establishments and technical schools. Several weeks were devoted to that work.

It had been a part of the original programme to visit the South-European manufacturing countries, and it seemed particularly desirable to explore the more interesting manufacturing districts of Switzerland, and to learn something of the extent and the peculiar characteristics of method of those industries in which they are recognized as leading all Europe; but time did not permit the carrying out of this portion of the plan. But, although unable to visit Switzerland to correct the impressions formed at Vienna by a personal inspection of the manufacturing districts, the writer is indebted to the kindness of a colleague on the International Jury for valuable published statistics and general information.

In consequence of the scarcity of products of the soil, it is necessary, to compensate for this scarcity, for a large portion of the population of Switzerland to follow manufacturing industrial pursuits.

Swiss industry is impeded by a deficiency of raw material, especially of coal and iron, by its continental position and its elevation above the sea, and also by the fact that it is surrounded on all sides by countries having protective tariffs. It is favored by the abundance of water-power at its command, which will be still further increased when the manufacturing interests become capable of taking possession of the cold, higher regions of the Alps. It is also favored by a complete liberty of trade and by a restless tendency to open new roads, which inclination overcomes local impediments, and enables Swiss productions to be brought into all the markets of the world. Numerous establishments have now adopted steam-power together with water-power, and there are already manufactories employing steam-power only.

324. COTTON-MANUFACTURES.—Among all branches of industry the most important are:

(*a.*) The cotton-manufactures, the seat of which was originally the eastern portion of Switzerland and in the cantons of Zurich, Aargau, Glarus, St. Gall, and Appenzell, and which gradually spread throughout the cantons of Zug, Thurgau, Schaffhausen, Schwytz, Soleure, Bern, and several others. It consists principally of cotton-spinning, and, according to the census statistics of 1870, the following are approximate figures for the number of spindles:

	Spindles.		Spindles.
Zurich	684,566	Appenzell	4,314
Bern	83,412	St. Gall	218,512
Lucerne	18,636	Grisons	33,122
Uri	....	Aargau	410,434
Schwytz	75,060	Thurgau	50,146
Unterwalden	2,400	Ticino	13,028
Glarus	254,468	Vaud	1,397
Zug	111,012	Valais	......
Freyburg	60	Neufchâtel	......
Soleure	28,526	Geneva	......
Basel	44,148		
Schaffhausen	26,110	Total	2,059,351

In 1860 the total number was 1,602,109 spindles; or an increase of about 457,242 spindles has taken place from 1860 to 1870.

Assuming the annual consumption per spindle to be 28 German pounds, (31 pounds English,) and the yarn produced to amount to 25½ pounds, (28 pounds English,) on the assumption that No. 45 is the average number for textile fabrics produced in Switzerland, then, from the above, we have an annual consumption of raw cotton amounting to 52,000,000 pounds, (63,200,000 pounds English,) and an annual production of about 52,500,000 pounds of yarn, (57,700,000 pounds English.) A portion of this is exported into Germany, Austria, France, and Italy, while another portion is woven in the country, principally in the cantons of Zurich, Aargau, Glarus, St. Gall, Appenzell, and Zug.

325. Another branch of industry, that of power-loom weaving, which has of late years assumed considerable importance, also absorbs no inconsiderable quantity of yarn of all numbers, for the manufacture of embroideries, of machine-thread, combed-wool yarn, &c.

The fabrics thus produced support the dyeing and printing industries, of which the most important seats are the cantons of Glarus, Zurich, Aargau, and Thurgau. The principal seat of the business of weaving of colored goods is in the cantons of St. Gall, Thurgau, Zurich and Aargau, and Appenzell; and large weaving establishments exist in Wald, in the canton of Zurich, manufacturing fine muslins, the greater part of which are subsequently worked up in the extensive embroidering establishments of the two first-named cantons.

326. EMBROIDERY.—Embroidery, one of the most important branches

of the Swiss cotton-manufactures, is divided into (1) hand-embroidery, (2) broad embroidery, by means of looms, and (3) into power-loom chain-stitch, or crochet-embroidery.

Appenzell, Inner Rhodes, is the headquarters of hand-work, and some is produced in the valley of the Rhine and beyond the Swiss frontier. Swabia and the Bregenz forest also produce hand-embroidery.

More than 4,000 machines are in use in the manufacture of the second kind of embroidery, principally in the cantons of St. Gall and Appenzell, and lately in Thurgau, while crochet-embroidery forms a later branch of industry, in which small machines with one needle and larger ones with from 12 to 44 needles are used.

327. (*b.*) THE SILK-INDUSTRY stands at the head of the manufacturing pursuits of Switzerland in the magnitude of the trade, showing an annual exportation of 215,000,000 of francs, ($43,000,000.) Zurich is the most important center of manufactures of silk goods, but Bern, Basel, Schaffhausen, Aargau, Glarus, Thurgau, and Grisons share in this industry. Zug, Schwytz, and Unterwalden work for Zurich. Almost a monopoly of the manufacture of silk ribbons is held by Basel, from whence it has been introduced to a slight extent into the Bernese Jura and into the canton of Soleure. Some silk-spinning is also done at Lake Zurich and at Aargau, and the floss silk spinning of Basel, Zurich, Schwytz, Aargau, and Bern is a somewhat important business.

328. (*c.*) THE WATCH AND CLOCK MANUFACTURE, of which the principal seat is in the Neufchâtel, Jura and in Geneva, has recently spread into the neighboring cantons of Bern, Soleure, and Vaud. More than 200,000 watches are annually produced, and the export is considerably more than 100,000,000 francs ($20,000,000) in value. The import of raw material and tools amounts to more than 8,000,000 francs, ($1,600,000.) In this business a thorough classification and division of labor is carried into the smallest details. Connected with it is the manufacture of music-boxes, principally in Geneva and in the district of St. Croix, in Vaud, which latter alone produces about 100,000 of these pleasing toys per annum. In Geneva the manufacture of jewelry is also carried on extensively.

329. (*d.*) WOOLEN MANUFACTURES are carried on in Zurich, Bern, and Glarus, not, however, to a sufficient extent to supply domestic demands. It is, however, promising to assume considerable dimensions, and extensive establishments for the manufacture of worsted and of twine are being built in the cantons of Thurgau and Soleure.

330. The linen-industry in the Emmenthal of Bern, and at Burgdorf and Langenthal, does not produce sufficient to supply the consumption of the country.

331. (*e.*) STRAW-BRAIDING gives employment to the population in several districts of Switzerland. The production is not very considerable. The work of Aargau, from the village of Wohlen, has a wide reputation for its elegance as well as for its artistic designs.

332. (*f.*) THE MANUFACTURE OF MACHINERY, for which the other branches of industry create a demand, has not been confined to supplying this immediate demand.

Although compelled to contend with great difficulties in consequence of the necessity of importing nearly all raw material under high rates of duty, Switzerland has been able to secure a good reputation both in its own and in foreign countries, and to export successfully. The Swiss furnish steam-engines, steam boilers, heaters, and gas-fixtures, locomotives, steamships, all kinds of motors, machinery of transmission, cotton and woolen machinery, embroidering-machines, paper-machines, hand-tools and machine-tools of all kinds, iron bridges, rolling-stock for railroads, and agricultural machinery. These establishments are usually provided with founderies. This industry is represented in almost all the cantons of Switzerland; the main centers are, however, in the cantons of Zurich, Schaffhausen, St. Gall, Soleure, Aargau, Basel, Bern, Freyburg, Vaud, and Geneva. Small machine-shops are found wherever any branch of industry creates a demand.

333. Switzerland possesses several blast-furnaces in the Jura, which are said to produce a very superior iron from the ore mined in the neighborhood. The total production of the Swiss Jura is about 7,500 to 8,000 tons of pig-iron and plate and bar iron per annum. This is but a small part of the consumption of the Swiss iron-manufactures. Switzerland annually imports and works up at least 50,000 tons of pig-iron, bar and plate iron, castings and steel, inclusive of railroad materials.

334. Among industries of less note are the following: The manufacture of mathematical and philosophical instruments in Aargau, Zurich, Geneva, and Bern; of pianos, in Zurich and Basel; that of parquetry, in Valais, Freyburg, Bern, and Lucerne; of carved work in the highlands of Bern; the manufacture of a superior kind of paper in Basel, Zurich, Aargau, Soleure, Vaud, Geneva, Neufchâtel, and in other localities, and the manufacture of earthenware in the cantons of Bern, Schaffhausen, and Ticino. There are about 500 tanneries, of which the greater number are situated on the boundary-line between the Alps and that part of the country devoted to agriculture.

CHAPTER II.

MANUFACTURES IN GERMANY.

MANUFACTURES OF MACHINERY—THEIR DISTRIBUTION AND GROWTH; MANUFACTURES OF METAL GOODS; TEXTILE MANUFACTURES; WOOD AND PAPER MANUFACTURES; HISTORY OF THE MANUFACTURE OF MACHINERY; PRIME MOVERS; TEXTILE MACHINERY; LIGHT MECHANISM; MACHINE-SHOPS AND THEIR PRODUCTION; PROGRESS OF INVENTION; COTTON-MACHINERY; SEWING-MACHINES; STOCKING-FRAMES; LOOMS; PAPER MACHINERY; FLY-PRESSES; MACHINERY OF THE TOOL INDUSTRIES; MACHINE-TOOLS; PUMPS AND BLOWING-APPARATUS; METROLOGICAL APPARATUS; RAILROAD-PLANT—LOCOMOTIVE-BUILDING—CAR-BUILDING—USE OF STEEL—IMPROVEMENT OF ROLLING-STOCK.

335. MACHINERY—EXTENT OF MANUFACTURES.—The German Empire is now the grandest manufacturing nation of continental Europe. Its intimate connection with the United States, in which latter country so many citizens have had political and social relations with both governments, makes the industrial standing of Germany a matter of especial interest. The early and unintermitted development of technical education, in which this nation leads all others, is another circumstance which lends especial interest to the study of these economic conditions.

The distribution and extent of the German productive industries are stated to have been largely determined by her originally more peculiarly exclusively mining-industry. In intimate connection with the extension of mining and smelting in this country have arisen the manufactures of machinery and important improvements in the means of transportation. The former industry and the fabrication of textile goods have developed the latter within the last half century in Rhineland and Westphalia, in the kingdom of Saxony and in Alsace.

Thirty-two years ago (1841) there were no locomotive or car manufactories in Germany. Now Germany produces yearly about 1,000 locomotives and 30,000 cars, valued at from 17,000,000 to 30,000,000 thalers. Berlin, Carlsruhe, Esslingen, Graffenstaden, Chemnitz, Hanover, and Cassel form, with other cities, the principal seats of this manufacture. By increasing the tractive power of the locomotives and the capacity of the cars, it has been possible to more than counterbalance the rise in price of labor and of coal. Three establishments in Chemnitz alone have produced during the last thirty years over 30,000 power-looms, carding-engines, spinning-machines, and similar machines, containing more than 1,500,000 spindles. Chemnitz also leads the German machine-tool industry. The domestic sewing-machine industry is even stated to be competing with the foreign; manufactories in Berlin and Dresden are stated to be capable of furnishing from 50,000 to 100,000 machines annually. The manufacture and introduction of agricultural machinery is slowly gaining a position in the market. The manufacture of printing-presses has always been a prominent business here, where the invention of the art of printing was made. Large numbers of printing-presses are furnished for exportation, especially to Russia.

The magnitude assumed by the business of manufacturing machinery within a short time may be seen in the fact that there were imported 217,225 cwt. of machines in the year 1868; at the same time there were exported 280,960 cwt., while the corresponding figures for 1872 were 663,720 cwt. imported, and 771,209 cwt. exported.

336. Metal goods.—The metal-ware industry has retained its original leading position. Formerly it had its seat in South Germany, but lately it has been moving northward into the mountainous countries bounding Rhineland and Westphalia. The manufacture of cutlery, tools, and weapons of war has been largely developed in parts of Westphalia, as Hagen, Altena, Iserlohn, and in parts of Rhineland, as Solingen and Remscheid. The manufacture of sewing-needles, founded three hundred years ago by laborers from the Spanish Netherlands, and the manufacture of iron and steel ware in Thuringia—in Suhl, Sömmerda—as well as in several cities of Würtemberg and Bavaria—Heilbronn, Nuremberg—have assumed an important place in the market. Berlin is famous for its weapons, cast-iron railings, forged and locksmith's ware. Articles of lead, tin, zinc, brass, and bronze are principally manufactured in Berlin, Nuremberg, Fürth, Munich, Cologne, and Hanover. The weight exported of these articles in 1872 was 307,998 cwt., while only 104,523 cwt. were imported.

The following figures are given for iron and steel products for the last five years:

	Imports.		Exports.	
	1868.	1872.	1868.	1872.
	Cwt.	*Cwt.*	*Cwt.*	*Cwt.*
Sewing-needles, steel springs, &c	2, 591	4, 231	30, 835	20, 165
Fine iron ware	7, 041	11, 626	27, 915	43, 144
Rough-forged and cast-iron ware	245, 628	2, 155, 967	799, 384	2, 312, 697

337. Textile fabrics.—The industry of textile fabrics equals in importance that of metals. In the year 1861, 800,000 persons were employed; an equal number of looms and about 4,000,000 finishing-spindles were in use. In the mean time the number of inhabitants of the towns principally engaged in this business has increased 50 per cent. The industries of spinning and weaving are carried on principally on the banks of the Lower Rhine. This is probably owing to the influence exerted by the cities of Flanders and Brabant in the middle ages.

At the same time, the spinning of flax and the manufacture of linen have acquired a greater importance in Westphalia, Silesia, and Saxony. They had been in a critical condition for many years, in consequence of the discouragements incident to passing from hand-spinning to machine-spinning, and they had partially lost the market.

The districts of Aix-la-Chapelle and Dusseldorf, the province of Brandenburg, the Saxon district Zwickau, and the countries of Upper Franconia, the Palatinate, Würtemberg, Alsace, and Lorraine are distinguished for their woolen fabrics. Of shawls and carpets, Berlin is the principal producer. The exports of woolen fabrics exceed the imports by about 200,000 cwt.

	Imports.		Exports.	
	1868.	1872.	1868.	1872.
	Cwt.	*Cwt.*	*Cwt.*	*Cwt.*
a. Woolen yarn	271, 507	344, 256	73, 933	144, 923
b. Woolen articles	74, 979	166, 590	292, 347	360, 302
c. Carpets	2, 541	7, 657	4, 032	10, 620

The value of exports has been estimated at 10,000,000 thalers.

The growth of the cotton-industry can be traced back to the beginning of the last century. As the official statement runs: "It attached its first threads to the woolen industry, at the side of which it now stands as an equally strong competitor." When the continental system of the first French empire stopped the importation of English twists, numerous spinning-mills were founded on German territory, and these have risen to great importance, though only after passing through several dangerous crises. In Chemnitz cotton-spinning machinery has been manufactured and used to a considerable extent since 1826.

The total production of cotton fabrics amounted to 1,650,000 cwt. in 1871, having been 1,000,000 cwt. in 1860, this covering not only the domestic, but also a part of the foreign demand. In the year 1872, 221,512 cwt. of cotton fabrics were exported; at the same time, only 49,059 cwt. were imported. On the other hand, the importation of cotton yarn in 1872 amounting to 456,863 cwt., exceeded the amount of exportation in a similar manner, the latter being only 98,800 cwt.

The manufacture of silk and mixed goods has its centers at Crefeld, in Elberfeld-Barmen, and at Berlin. It consumed in the year 1871–'72, 980,000 kilograms of silk and silk thread, valued at 27,500,000 thalers, while it used in the year 1843–'44 only 350,000 kilograms, valued at nearly nine million thalers. The value of these fabrics may be estimated at 50,000,000 thalers. In the year 1872, 14,041 cwt. of silks were imported, while the export amounted to 39,708 cwt.

338. WOOD AND PAPER.—The industry in wooden ware, especially in the manufacture of furniture, is of great economic importance. German furniture in very early times was of great value, and still has a high reputation. Subsequently this branch of trade failed with the decadence of

national architecture, and it has not fully recovered. The trade has only re-assumed importance within the last two decades, and then only in the larger cities of Berlin, Munich, Stuttgart, Dresden, Cologne, and Mayence. Omitting the statistics of rough-turned work and of wood cut into veneers, exports of furniture exceed the imports in value. In the year 1872, the exportations amounted to 310,220 cwt., and the imports were 58,270 cwt., while in the year 1868 the figures were 207,510 cwt. and 29,970 cwt., respectively.

The manufacture of paper and paper articles is now extensively carried on throughout the whole country. About one thousand paper-mills and factories are employed, generally merely manufacturing the cheap and common goods, in preference to the more expensive qualities. They have, however, already arrived at an annual production of machine-paper valued at 50,000,000 thalers; and in the year 1872 they were able to supply foreign markets with 20,000,000 kilograms more than their importations, after having satisfied domestic demands. The treatment of wood for the purpose of manufacturing paper-pulp is largely practiced. Paper-hangings are manufactured in great perfection in Hessen, Rhineland, Franconia, Thuringia; paste-board and card-work in Frankfort-on-the-Main, Dresden, and Leipsic. Articles of *papier-maché* are made in Thuringia and the mining districts.

339. MACHINERY, AND HISTORY OF ITS MANUFACTURE.—The official statement made to the International Jury relative to the manufacture in Germany of machinery and means of transportation was quite full, and the following account is undoubtedly accurate.

Germany seems to have taken an active part in the development of this industry during the last century. The spinning-wheel and the watch and clock, the steam-engine, the invention of which Otto Von Guericke took part, and one form of which was invented at the German University, Marbourg, the water-pressure engine which is claimed to have been first developed in Germany, and the fly-press and its applications, had all been extensively introduced at a very early date. In entering upon the manufacture of these machines, Germany has been behind her neighbors. The business took shape very gradually, and the exact date cannot be given, but it occurred at about the time when Germany began to rally from the effects of those great wars which occurred at the beginning of the present century, which changed its political relations so completely. About 1820, Germany, stimulated by the influence of England and Belgium, began to manufacture machinery for the general market.

340. PRIME MOVERS.—At about that time the manufacture of steam-engines was taken up in Prussian Rhineland. At first the production was limited to supplying the demands of the mining and smelting industries, which were then the most important in the country. The steam-engine manufacture of Rhineland and Westphalia still has there its largest market. Recently the manufacture of gas-engines has been

taken up with that of steam-engines in the above district. This business arose upon the demand of the smaller industries for prime movers of moderate power. Several machine-tool manufactures have also been added to the above on the Lower Rhine, among which the principal are the machines used in mining and smelting. They were not, however, well represented in the Exhibition.

On the Upper Rhine, and in the southwest of Germany, the manufacture of water-wheels, especially of turbine water-wheels, is developing rapidly, water-power being there largely available. This is also the case in Alsace.

341. TEXTILE MACHINERY.—The business of manufacturing machinery for cotton-spinning, weaving, and finishing has its main centers at Mülhausen and Thann, and has been greatly developed in Alsace by the progress of the manufacture of textile fabrics. At the same places and in Graffenstaden the manufacture of machines for working metals and wood is also growing. On account of the extensive production of textile fabrics, machinery adapted to that use was produced at an early date in Saxony, both for cotton and for wool, and to a less extent for linen goods. The London Exhibition of 1851 induced the capitalists of Saxony to enter upon machine-tool manufacture. This is at present one of the most extensive branches there carried on, furnishing machines for working metal and wood which are of excellent quality.

342. LIGHT MECHANISM.—The Prussian province of Saxony and the neighboring districts have developed the manufacture of sugar-making machinery also. The manufacture of manometers, or pressure-gauges, and other attachments to steam-boilers, is actively carried on upon a grand scale in the establishment of Schäffer & Budenberg, in Magdeburg. Their spring-gauges are sold all over the world. These and other establishments have also begun to build parts of machines, and this branch of their business is rapidly growing and promises to prosper. The articles now manufactured there are principally valves, cocks, and small brass goods. The manufacture of parts of machinery of transmission, such as coupling, wheels and pulleys, has not yet been fully organized, and they are still only made to order and are not given standard forms.

343. MACHINE-SHOPS.—At Berlin, the manufacture of machinery was commenced by the iron foundries, which gradually developed, and were transformed into machine-shops. These at first produced all kinds of machinery, but they gradually each assumed a special character.

The manufacture of locomotives is the most important of these industries. The building of machine-tools, steam-engines, hot-air engines, printing-machinery, machines for brewing, sugar-making machinery, agricultural implements, and large numbers of sewing-machines, and those manufactures lately developed, are all extensively carried on in Berlin. This city has become one of the most important centers of the German machine-industry.

Machine-shops are, however, distributed over all Germany. The following figures exhibit the weight of imports and exports of machinery from 1866 to 1871:

Year.	Import.	Export.
	Centners.	*Centners.*
1866	226, 023	144, 157
1867	226, 914	209, 129
1868	217, 225	280, 960
1869	292, 566	411, 088
1870	287, 221	432, 367
1871	315, 424	482, 917
1872	663, 720	771, 209

An increased consumption of machinery of foreign make is indicated, and also a continual increase in the export of machinery. Germany did not fully meet its own demand for machinery at the time of the Paris Exposition of 1867, but it now assists in supplying the markets of the world.

344. PROGRESS OF INVENTION.—The earliest manufacture of machinery occurred in the year 1801. The first extensive production of hand-looms was by Hanbold, at Chemnitz, 1826. Pickers and lappers were first built in 1842. From that time this manufacture gradually developed by the invention of important improvements at home, such as the construction of Hartmann's fine carding-engine for short wool, (Saxon Patent, v. 13, December, 1842,) and by the independent development of the power-loom by Schönherr, in Chemnitz, 1836; of the cloth-finishing machine and the shearing-machine by Thomas, of Berlin, 1845; Gessner, in Aue, 1853; and by Pressprich, at Grossenheim, of his fulling-mill, in 1854. The self-acting carding-engines by Schimmel, Pfaff, Wiede, and others; the calico-printing machines and dyeing and finishing machines by Hummel, of Berlin, 1840, and by Riesler, at Zittern, and the knitting-machines made by Voight, at Kappel, 1860, are also noteworthy. Eight hundred and seventy-eight patents have been issued in Saxony during the last forty years (1833–'72) on inventions connected with the manufacture of textile fabrics, and of these 574, 65.4 per cent., were taken out by Saxons and 304 by foreign inventors.

345. *The manufacture of sewing-machines, from American designs*, dates as far back as the year 1854. Moore, of Berlin; Hofmann, of Hesse; Huber, of Leipsic, build sewing-machines, and the workmen come from among the best classes of mechanics. The most important seats of this manufacture are Dresden, Hamburg, Berlin, Limbach, Chemnitz, Mannheim, Frankfort-on-the-Main, and Carlsruhe. The total production up to the end of 1872 has been estimated at 300,000 machines. The factory of Clemens Müller, in Dresden, was founded in 1856, and furnishes 18,000 machines annually. Its capacity has been increased up to 60,000 or 80,000. The sewing-machine factory (formerly that of Frister & Rossmann) in Berlin furnished 16,971 machines in 1872, and

has already built 3,610 in the first two months of 1873. It has a capacity for the production of 42,000 machines annually.

346. The development of stocking-frame manufactures occurred independently of that of other machines used in textile industry. The introduction of the machine, with a peculiar construction in wood, may be traced back to the middle of the seventeenth century in the Saxon Erzgebirge. A reliable estimate gives the number of looms built from 1784 to 1863 at 58,300. In 1770, the iron frame was introduced by Aurich at Grüna, Esche at Limbach, and by Ganzange in Zeulenroda. In 1853, Heinig, of Neukirchen, invented his machine, replacing the former arrangement, which allows the hand-loom some chance of competition with the power-loom in manufacturing. In 1842, the first English circular loom was set up at Stollberg, but the building and manufacture of these looms only began about the year 1850 in Limbach, Stollberg, Mitweida, near Schwarzenberg, and in Chemnitz. Circular looms have also been manufactured at Stuttgart, by Stückler & Perrot, since 1862. The ribbon-loom, a sort of power-loom upon which narrow ribbons are manufactured, has a history going still farther back. They were introduced from Holland at the beginning of the seventeenth century. Their use was forbidden in 1685 by an imperial decree, and they were again introduced in 1718, at Charlottenburg, and were finally, in 1765, allowed by a special decree of the elector. The manufacture of these and of other machines for lace-work, as braiding-machines, is carried on in small shops, especially in Berlin. They are also built in and about Annaberg, in Saxony.

347. Other countries have competed more effectively in Germany in the sale of machines for paper-manufacture than of those used in textile industry. Switzerland has been most prominent in this competition. The manufacture of rag-engines had been undertaken by many machine-shops, but the building of paper-machines for endless web was for a long time only attempted occasionally. This branch of manufacture is even now the specialty of a single firm, Golzern, in Grimma, Saxony. Machines for making paper-pulp from wood were invented and developed by Henry Völters, at Heidenheim, on the Brenz. Their manufacture is now carried on by Decker Brothers & Co., of Cannstadt. Up to the end of 1872, there had been built in Europe 212 of these machines, and in America, as stated, 150, a total of 362 such machines requiring about 22,000 horse-power, capable of manufacturing about 6,000 cwt. of pulp. In Germany there are about 77 real Völter machines in use, and numerous imitations.

348. The inventor of the fly-press, Fr. König, who built the first printing-machines in London for the Times, in 1817, started a factory which was devoted to the manufacture of these machines, in the Oberzell convent, near Würzburg. This factory supplied all Europe. It had built and sold 1,898 fly-presses up to the beginning of 1873, being distributed, by date, as follows:

1817 to 1830	52
1830 to 1840	54
1840 to 1850	186
1850 to 1860	314
1860 to 1872	1,292
Total	1,898

Of these about 60 per cent. were sold in Germany and 40 per cent. were sent to other countries. Russia has taken about 350 presses. The number of workmen employed exceeds 400. A second factory has recently been built near Würzburg.

Dingler, of Zweibrücken, has been engaged in the manufacture of iron hand-printing presses since 1841. The total production was 1,512 machines up to the end of 1872, of which Germany took 246, Switzerland 108, and Russia 148. Printing-machinery is also manufactured in Berlin, by G. Sigl, Fred. Jänecke, and others, and in Leipsic. Machines for lithographing, copper-plate printing, and book-binding have been made extensively at Offenbach, on the Main, by Heim Bros.

349. The manufacture of machines for the production of articles of food and luxury is less localized. Magdeburg produces machines and apparatus used in the manufacture of sugar; Dresden supplies the market for chocolate-machinery; Chemnitz furnishes brewers' machinery; Brunswick builds ice-machines; Stuttgart, Leipzic, and Dresden make machines used in the manufacture of cigars. The manufacture of grain-husking machines has been actively carried on, since about 1866, at Frankfort-on-the-Main, by the firm of Seck & Co. At the end of 1872, 515 machines of this kind were sold, of which 241 were for Germany, the annual production being about 100.

350. The development of the German machine-tool business was greatly retarded by the general custom of each machine-shop building its own machinery. It is true that Reichenbach, in Munich, (1804,) constructed several original and ingenious machine-tools. He built the first file-machine. The first impulse toward a general use of machine-tools was given by the British, and through the exertions of Beuth, of Berlin, who imported the best English models into Germany at the expense of the Prussian government, and who had them copied, and then made them familiar to the German manufacturers by *advertisement.* A. Hamann, of Berlin; Mannhardt, of Munich, and Henschel, of Cassel, first attained a reputation in this work.

The second period of development was that in which the simple copying of foreign designs was to some extent given up, and building on original plans was commenced. This policy was inaugurated about 1852, when several manufacturers of Chemnitz commenced the manufacture of machine-tools as a specialty. Since that time, Chemnitz has sent machine-tools to all the countries of Europe, to South America, and to Egypt. Although the manufacture of machine-tools originated in the demands of the manufactories of machines required in the textile industries and of steam-engines, it owes its greatest development principally to the recent development of methods and means of transport, and especially to the demands of railroads for rolling-stock. Machinery for the manufacture of fire-arms has become important; and of these tools Chemnitz furnished a large number to the great gun-factories of Westphalia, to the royal Prussian manufactory of fire-arms, to the imperial Russian arsenals and naval stations, and to Italy and Servia. The total production of the "Chemnitzer Werkzeugmaschinenfabrik," (I. Zimmermann,) amounted, at the end of the year 1872, to 10,600 machines, and that of the "Sächsische Maschinenfabrik," (Rich. Hartmann,) to 2,645 machine-tools of all kinds.

After Chemnitz come Graffenstaden and Mülhausen and Berlin; Offenbach, on the Main, Stuttgart, Carlsruhe, Hamm, in Westphalia; Aue, near Schneeberg, all towns of importance in the machine-tool business. I. Banning, of Hamm, furnished to date 350 steam-hammers, with a weight of "tup," or drop, varying from 2 cwt. to 120 cwt. Kirchei's, of Aue, since 1863, has made a specialty of tinsmith's tools. He built 642 machines in the year 1870.

A peculiarly German specialty is the manufacture, by Uhlhorn, at Grevenbroich, of coining-presses fitted with a lever combination. The first machine of this kind was furnished by Dietrich Uhlhorn to the mint of Dusseldorf in 1818, to replace a screw-press, of French make, which had been broken. Now twenty-three states of Europe and several foreign states are said to employ 175 of these machines in their coinage. It is recognized as a most efficient machine.

Recently the marked influence of the manufactures of the United States is perceivable in the production of machine-tools in Germany, especially in wood-working machinery.

351. The manufacture of pumps, blowing-machinery, and ventilating-apparatus has not yet been completely separated from that of steam-engines and machine-tools. Independent and extensive manufactories have, however, been established for the manufacture of steam fire-engines at Dresden, Heidelberg, Aix-la-Chapelle, Stuttgart, and Berlin. The production of steam fire-engines has continued an independent industry in Chemnitz and Berlin.

352. Instruments required in the observation and measurements of steam-pressures, the measurement of speeds, and of the amount of motive-power demanded by machine-shops, were originally of foreign make, or were occasionally made in the shop where employed. They may well be separately manufactured on a large scale, as the delicacy of the work is exceptional. Manufactories have been erected in Berlin and Magdeburg within the last twenty years for the manufacture of spring pressure-gauges, the largest of which establishments, that of Budenberg & Schäffer, in Buchau-Magdeburg, furnished, up to the end of 1872, 235,000 gauges. The German laws regulating the erection of steam-

boilers, which direct that each boiler must have at least one pressure gauge, have been peculiarly favorable to the development of this branch of industry. The manufacture of gas and of water meters is of equal importance, and is a prominent branch of business in Berlin, Dresden, and other places. The single establishment of Siemens & Halske, in Berlin, had furnished 11,060 water-meters up to the end of 1872, all of which were of original design. On the other hand, the production of velocimeters and of dynamometers has only occupied a single establishment.

353. RAILROAD-PLANT.—In the early days of railways, about 1840, there were no facilities for supplying rolling-stock. There was a complete absence of establishments for building locomotives, and these were necessarily imported both from England and America. Soon, however, men were found capable of undertaking this work. Among them, the name of August Borsig is best known. His eminently practical good sense assisted effectively in the development of this branch of industry in Germany. Borsig recognized the fact that it was of primary importance to obtain a reputation for good work, and he therefore spared no pains to make his locomotives superior both in material and workmanship. A large iron mill, which existed many years at the gates of Berlin, was erected by this "man of iron will," who, not feeling satisfied with the guarantee offered by distant manufacturers, desired to have his boiler-plate, axles, and other details in iron manufactured under his own eye. Such energy was naturally crowned with full success. This had a very beneficial effect upon the German manufacture of locomotives.

The superiority of Borsig's work, which soon became generally acknowledged, crushed out all competition, even that of native manufacturers, until they determined to attempt to produce the same quality of work. It is for this reason that this branch of industry has succeeded so well in Germany, and it is claimed that it has not only been able to meet domestic demands, but it has also been able to compete successfully with England and other foreign countries. Large locomotive-works now exist in Königsberg, Elbing, Stettin, Berlin, Hanover, Chemnitz, Cassel, Munich, Carlsruhe, Esslingen, and in Graffenstaden and Mülhausen, all together being capable of building more than 1,000 locomotives annually, valued at 50,000,000 marks, ($12,000,000). As an indication of the number exported, it may be stated that Borsig's establishment built 1,031 locomotives from April 1, 1867, to April 1, 1873, and of these 300 went to Russia and 30 to Austria, Holland, and Java.

354. Equally encouraging progress has taken place in the manufacture of cars. With exception of the axles, wheels, and springs, cars were first made of wood put together with bolts and angle-irons. Gradually iron has taken the place of wood, and now the floor-frames are built wholly of iron on many roads, their wear and stability being, it is said, thus considerably increased.

The extended employment of cast-steel instead of cast-iron is an improvement which Germany claims as peculiarly its own. It was at first an attempt to displace iron by a material which then cost about six times its price, and which had until then only been manufactured on a small scale. Werner, at Carlswerk, near Neustadt-Eberswalde, was the first to make cast-steel axles of good quality for railroad rolling-stock; Krupp, of Essen, invented an ingenious method of making weldless cast-steel tires, and Meier, of Bochum, cast excellent steel disk-wheels in one piece. These three inventions have found extensive application. Iron is almost displaced on some roads, with great advancement in safety and durability and in the working capacity of the cars. Even the comfort of traveling has been thus greatly increased. A great improvement has been made in passenger-cars. Instead of the open or half-open third-class cars used formerly, the practice is now becoming usual of providing even the fourth-class cars with heating-apparatus in winter and of lighting them up at night.

Car-building establishments are distributed throughout Germany in larger numbers than locomotive-works, and not only in the towns mentioned as the sites of locomotive-works, Chemintz excepted, but at Greifswalde, Görlitz, Breslau, Dusseldorf, Hagen, Cologne, Deutz, Frankfort-on-the-Main, Mayence, Brunswick, Hamburg, and Ludwigshafen. These establishments also export extensively, turning out about 30,000 cars annually, valued at about 90,000,000 marks, ($22,000,000.)

355. By the employment of higher steam-pressures, and by a more complete utilization of the adhesion of the locomotive, its tractive power has been increased threefold over the earlier practice. The capacity of the freight-cars, as compared with their weights, has been increased considerably. While formerly the tare-weight amounted to about one-half the gross-weight, it has now fallen to about one-third or one-fourth.

In consequence of these improvements, rates of freight have been reduced without decreasing the income of the roads, and in spite of the higher prices of materials and labor. The official report to the International Jury, from which these facts were principally obtained, may therefore truly consider these branches of industry as the great levers in national economic advancement.

CHAPTER III.

GERMAN MANUFACTURING ESTABLISHMENTS AND TECHNICAL SCHOOLS

DRESDEN—THE POLYTECHNIC SCHOOL; FREIBERG—THE BERG-ACADEMIE; BERLIN—THE BORSIG LOCOMOTIVE WORKS—THE BAU ACADEMIE—THE GEWERBE SCHULE; ESSEN—KRUPP'S WORKS—KRUPP'S MINES AND SMELTING-WORKS—PRODUCTS OF HIS ESTABLISHMENT—KRUPP'S ORDNANCE—COMPARISON OF KRUPP'S WITH BRITISH AND AMERICAN DETAILS.

356. *Dresden.*—The first stopping-place after leaving Vienna was Dresden, the seat of a fine technical school and a favorite place of residence of Americans visiting Europe. There are no manufactures here that demand report.

The technical school is not well provided with apparatus, and its collection of models is not remarkable either for its extent or its interest. There are some excellent collections illustrating the processes of textile manufacture which are used in the course of instruction given by Prof. Dr. E. Hartig, a colleague on the International Jury, to whom the writer has been greatly indebted for valuable information. Among the models of machinery is a fine locomotive presented to the school by the builder, Richard Hartman, of Chemnitz. A model of a "Jonval" water-wheel was a reminder that it is here claimed that Henschel, of Cassel, invented this turbine, and that Jonval had seen it here some years before he brought it out as the Jonval wheel. The work done here by the students is unusually fine. They spend a large amount of time upon the preparation of elaborate theses. One student had made a very complete set of excellent drawings representing a windlass with its gearing; another had designed a neat-looking Fairbairn crane; still another had made designs for a cotton-mill, including buildings and the placing of machinery; another student had produced, as an original design, a Meyer valve-gearing, to which the Porter governor had been applied for regulation.

One of the best pieces of work exhibited by Prof. Weiss, who kindly acted as guide in the absence of other professors, was a set of drawings and specifications for the water-supply of a large city, and all necessary calculations to determine cost and relative efficiency of methods. The students give a considerable amount of time to such work, as is evidenced by the quantity of work accomplished. Sixteen hours a week are usually devoted to such problems in the drawing-rooms, and, in addition to this, the student attends lectures in the several auxiliary academic departments. Such designs as we were able to inspect were usually well made, and in some cases they exhibited a remarkable amount of inventive genius—a rare quality in Europe—and were invariably well proportioned. It is in such schools as this that the German youth are acquiring a knowledge of the science of engineering, and that skill in the work of the drawing-room which has done so much for their own country during the last quarter or half century, and which has enabled them to find their way into the best manufacturing establishments in the United States, and to monopolize so considerably some special departments of work. At home, where the shops and the professions are alike overcrowded, they find few opportunities for advancement. In the United States opportunities are vastly more frequent, and these graduates of German schools are taking advantage of them.

On the river at Dresden we noticed *Schiffmühle*, (floating tide-mills,) which were evidently finding plenty of work. A *Kette-dampf*, or steamer driven by the now well-understood system of chain-towage, was plying between the city and the smaller villages up the stream. Several long barges on the river were fitted with rude "balanced rudders," such as are generally supposed to have been original in the United States. Visiting the famous picture-gallery, we saw an old painting in which was shown a peculiar form of saw, upon which several patents have been issued in this country, and which is claimed to be one of the most valuable of new inventions; the picture was numbered 1748, and painted by Croch three hundred years ago.

357. FREIBERG.—While at Dresden, a day was taken for a visit to the celebrated mining-school of Freiberg, which is situated not far distant, in the midst of a hilly mining-country which resembles somewhat some of the pleasantest portions of New England. This old Saxon city contains the *Berg-Academie* to which so many American students are indebted for their knowledge of the theory and methods of mining. The surrounding country is rich in ores and minerals, and is interesting both to the metallurgist and the mineralogist. The town itself is quaint and interesting from the evident antiquity of the buildings which line its principal streets, but it contains nothing especially interesting to an engineer.

The school is in the city, and consists of a number of departments directly or indirectly connected with the work of instruction in mining-engineering. The high character of its work and the distinction obtained by its faculty have been long well and widely known, and, together with its exceptional advantages of location, these inducements have made it quite a successful institution.

The collection of models is an excellent one. Many of them have been made here, and a large number of duplicates have been made also for foreign schools. We found a considerable number, wholly or partially finished, for schools of mines in the United States. Among these models was one representing a mine with its shafts and its galleries, its hoisting and pumping machinery, and all accessory apparatus. It was worked by clock-work, and gave the visitor a very perfect idea of the general management of a large mine and of the method of working. A large number of models of pumps, water-wheels, and steam-engines, such as are commonly used in mines, gave one an excellent opportunity to study the forms and applications of such details. A model of a pair of direct-acting steam-engines, in section, was unusually well made; another represented the Cornish pumping-engine, and was made in metal. This could be driven either by steam or air. The price asked for it was 1,550 thalers. It was of about 8 inches diameter of steam-cylinder and 18 inches stroke of piston, constructed to a scale of 1½ inches to the foot from an original of 80 horse-power. A fine set of boring-tools, for mines or for artesian wells, was on exhibition; a good model of a blowing-wheel, a double blowing-engine, with one cylinder in section, several smelting-furnace models, filled with hot blast, and with cone and hopper charging-apparatus, models of puddling furnaces, and other equally useful models for mining schools were among the collections, and duplicates were to be had by purchase. These models were usually constructed in pear-wood, and were well made and nicely finished. The prices were moderate, but it requires a very long time to fill an order. Five men were employed in making these models, and the profit obtained from their work on material sold was sufficient to supply a considerable amount of valuable material to the school. Although this is an excellent and well-appointed school, it is a matter of congratulation that we now have equally good schools of mines in the United States, in which our young men may find equally good opportunities to acquire a knowledge of the subject, both by lecture-room instruction and by practical acquaintance with under-ground work. The importance of such knowledge in the development of the immense mineral resources of our country is well understood, and such schools are now frequently founded and are often well endowed. The profession of mining-engineering is an attractive one, and there are many young men in the United States whose tastes and mental powers are peculiarly well adapted to such work. We are, therefore, not at all dependent upon Europe, either for such material or for its education, and the working of our mines may be expected to be intelligently and profitably conducted, and our mining regions will be as rapidly developed as the growth of the nation and its agriculture and manufacturing industries may require.

358. BERLIN.—Returning to Dresden, we next took the train for Berlin, and rode through a pleasant but somewhat monotonous country. The planting of trees along all roads and along the borders of the fields was a feature which reminded an American of the fact that in the United States the importance, the vital necessity, of such compensation for the loss of the forests is not at all appreciated, and that the danger of serious results from the rapid changes of climate, such as invariably accompany the deforesting of a country, is becoming imminent. Public attention is slowly becoming attracted to this subject, and it is to be

hoped that prompt and intelligent legislative action may avert those consequences.

The country about Berlin is smooth and perfectly level, as it is through all that part of Europe, and the whole country is dotted with such windmills as were familiar to all in the United States a few years ago. The improved forms, now so common in this country, with self-adjusting sails and self-directing apparatus and regulation, are not seen in Prussia.

The *Borsig Locomotive-Works* are at Berlin. This establishment is one of the largest and most important of its class in Europe. It is stated to have supplied more than one-third of all the engines supplied to German railroads. The Borsig property consists of the locomotive-works, which are located in the city of Berlin, the boiler and forge shops, which are at Moabit, in the suburbs, and the iron and steel works, which are at the mines. Of these works but little can be learned, that is important to the engineer, in reference to their production. It was stated that up to 1870 the German roads had purchased 5,455 engines, of which 1,900 were constructed at the "Borsigsche Anstalt," in Berlin where 158 were made in that year alone, and that the capacity of that establishment is sufficient for the production of about 175 per annum. The "Gesellschaft für Fabrication von Eisenbahnbedarf" built in that year over 2,500 railroad-cars, for which the receipts amounted to 3,500,000 thaler, and the Moabit establishment produced over a thousand tons of apparatus. The number of workmen employed in the city is not far from 1,500, and their capacity is sufficient to work 2,000 men. They work eleven hours per day, and are paid from ten to fifteen thaler per week. The buildings are quite well planned and well arranged, and the new structures in course of erection were well disposed and well lighted. Of the tools many were old, but some new tools had been imported from England, which were of the best recent design.

In the locomotive-works the methods of work are quite similar to those observed in the majority of other establishments in Europe. Engine-frames are made from rolled plates and trimmed up by a machine of peculiar design, constructed for this work. It is fitted with four independent tool-posts, which can be moved in all directions by independent feeds; the direction of the cutting-edge is adjustable, to suit the direction of motion of the tool. The thickness of metal usually adopted is 30 millimeters, (1.2 inches,) but the tender-frames are of lighter plate, usually but ten millimeters thick. Wheels are invariably of forged iron. The boilers are usually of iron, rarely of steel. Fire-boxes are made of copper in nearly all cases; steel is experimentally adopted in a few instances. The tubes are often made of iron, with a portion added at the fire-box end which is composed of copper—a peculiarity of locomotive practice which we had not observed elsewhere.

At the boiler-works the riveting was all done by hand, so far as observed. The heads of rivets were usually made by the use of a former driven by a heavy hammer or light sledge, and the shape was usually that of the snap or hemispherical head. The practice, which is not uncommon in Great Britain, but which is rarely seen in the United States, of punching the holes somewhat smaller than it is proposed to finish them, and of enlarging by drilling to size, was quite generally adopted here. It makes good work, looks well, and is very strong. It is superior to the conical-headed riveting commonly seen in the United States, and some of our builders are adopting it even where the work is done by hand. In steam-riveting the snap-head is universally used.

The first locomotive built at the Borsig Works was completed July 21, 1841, by the founder, who has but recently died. He was greatly respected and beloved by his work-people, over whom he watched with paternal care. One of the evidences of this care is the large dining-hall and refectory, in which workmen are, when they desire, supplied with meals between 8 o'clock and 8.30 a. m., 12 and 1 at noon, and from 4 to 4.30 p. m. The married workmen usually go to their own homes, or bring their meals and eat here with the unmarried men, who usually obtain their food at this restaurant.

These works are supplied with iron and steel from branch establishments in Upper Silesia.

The Borsig Iron-Works were established in 1863. There are four blast furnaces, which yield about 30,000 tons per annum of manganiferous iron of excellent quality. There are also extensive puddling and steel works with three Siemens-Martin furnaces.

About 3,500 men are employed, and the 45 engines in the establishment are collectively of 4,400 horse-power. These works make excellent boiler-plates from pig from brown Silesian hematite ores, mixed with Styrian and Hungarian spathic ores. The following are averages of a series of tests recently made with samples of boiler-plates by Mr. David Kirkaldy. The length of the samples used in the experiments for tensile strains was in each case 18 inches, the ends for a length of 4 inches being made wider than the body of the sample. In the tests for bulging stress, discs 12 inches in diameter were cut out of the plates and pressed into an aperture 10 inches in diameter.

TABLE I.—*Tensile stress.*

	Thickness, inches.	Stress.		Ratio of elastic to ultimate strength.	Contraction of area at fracture.	Stress per square inch of fractured area.	Extension, per cent.	
		Elastic per square inch.	Ultimate per square inch.				At 40,000 pounds per square inch.	Ultimate.
Lengthway—								
Unannealed	.64	29, 125	53, 405	54. 5	27. 4	73. 492	4. 97	23. 8
Annealed	.64	28, 523	50, 466	56. 5	27. 3	70, 097	5. 93	42. 7

TABLE II.—*Bulging stress.*

	Thickness.	Stress in pounds; bulged, inches.				Ultimate.	
		50,000.	100,000.	150,000.	200,000.	Bulge.	Stress.
						Inches.	*Pounds.*
Unannealed	.640	.95	1.57	2.07	2.60	3.26	233,410
Annealed	.640	.90	1.49	1.95	2.39	2.69	223,375

TABLE III.—*Bending test.*

	Description.	Angle.	Effects.
		°	
Hot	Lengthway	180	Uncracked.
Do	Crossway	180	Do.
Cold	Lengthway	180	Slightly cracked.
Do	Crossway	57	Do.

Of the four samples submitted to bulging stress, one of the annealed and both the unannealed ones burst on arriving at the maximum strains recorded.

359. The *Bau-Academie*, of Berlin, is a technical school of high standing, which is educating 650 students—its full complement. Its course of instruction is almost purely scientific. The establishment has some very fine models in its extensive collections, the best of which are bridge-models. Some of these are very large and are perfect reproductions in all but size of the structures from which they are modeled. A very large and complete collection of architectural models in plaster is a very valuable feature. Every well-known form of structure and of detail is shown here, with occasionally the finer work exquisitely reduced to scale. The buildings are not of modern form, and the rooms are not as well arranged as are those of many other schools.

The *Gewerbe Schule* is also a technical school of admittedly high standing, and is probably one of the best in the *personnel* of the establishment, in its buildings, and in collections to be found in Europe. The director is Dr. Reuleaux, a well-known writer on subjects connected with mechanics and engineering, and a member of the International Jury, Vienna. The faculty is moderately large, and comprises among its members some of the best known among the younger scientific men of Germany. The buildings are not remarkable for either arrangement or construction, but some of the lecture-rooms are well fitted up, and especial care is taken in ventilation of those which are artificially lighted. This school has a remarkably fine collection of models of geometrical and mechanical apparatus. Several workmen are kept constantly employed in the little machine-shop of the establishment, and are continually enriching the already large and well-selected collections. The models are of a lighter and neater pattern than those usually seen in the cases of our own and of European schools, but as none are made for sale, they are likely to remain uncopied. The students do not work in the shop except when found unusually expert in the use of tools, and when they make special application for that privilege.

The course of instruction is largely by lecture, with such illustration as is possible by drawings and by the use of models. The work of the students is very creditable, and the institution is evidently prosperous, and it is doing a vast amount of good.

360. ESSEN; KRUPP'S WORKS.—At Essen, Prussia, are the works of Friedrich Krupp, the largest manufacturing establishment in the world. The proprietor gave to the International Jury an account of the growth and present condition of these enormous works, which was as interesting as it was instructive.

The cast-steel manufactory near Essen was established in the year 1810. It was conducted by Alfred Krupp from the year 1826, and was taken by him on his own account in 1848. The works have been very gradually but steadily developed. In January, 1873, the works covered an area of more than 4,784,000 square yards, of which about 900,000 square yards were roofed over. More than 12,000 workmen are employed, independently of about 2,000 who are supplied by contractors.

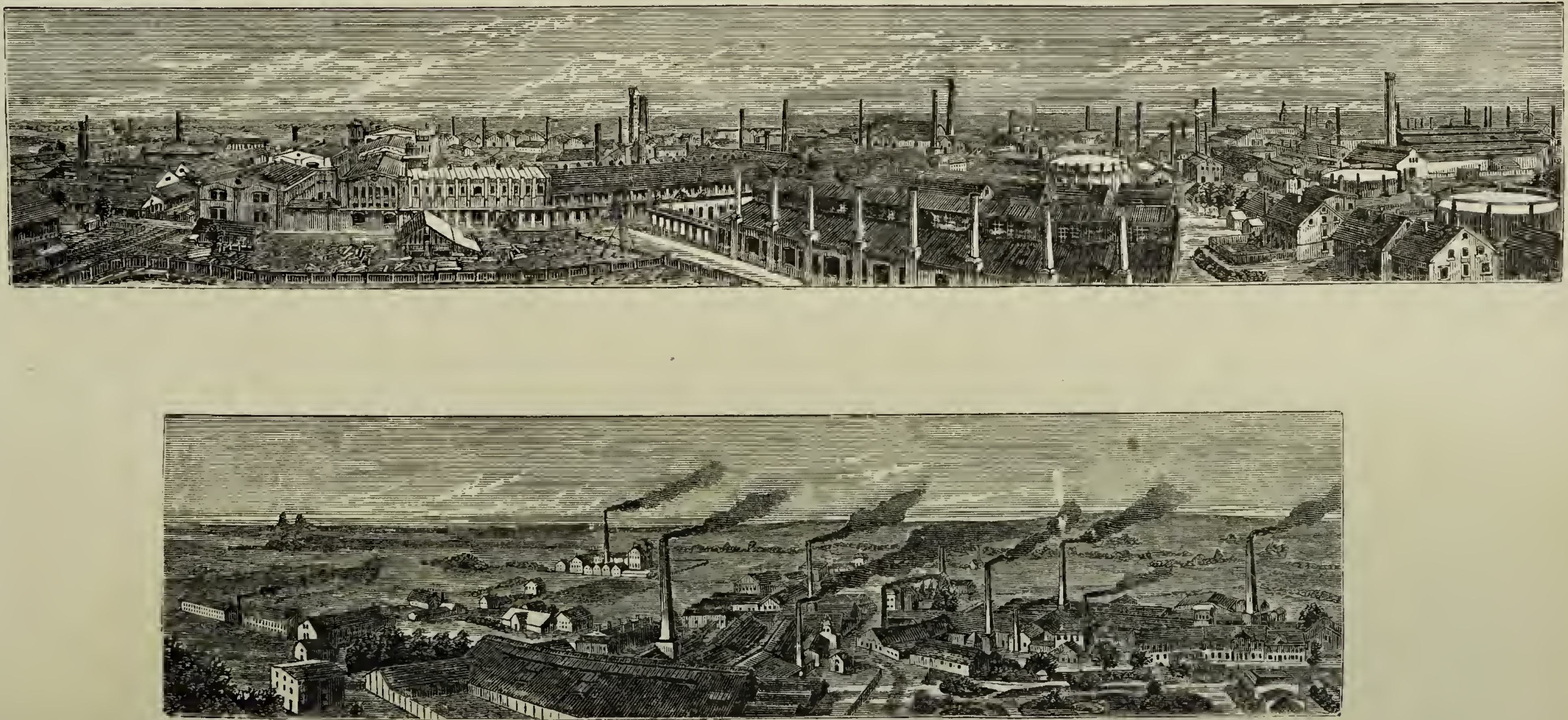
In the mines and smelting-works belonging to the firm there are employed about 5,000 workmen. The total number is about 17,000 men in all departments. The number of officers and salaried employés is 739.

The quantity of cast steel produced in the year 1872 exceeded 125,000 tons.

There are in operation 250 smelting-furnaces, 390 annealing-furnaces, 161 heating-furnaces, 115 welding and puddling furnaces, 14 cupola and reverberatory furnaces, 160 furnaces of other kinds, 275 coke-ovens, 264 smiths' forges, 240 steam-boilers, and 70 more in course of construction.

The total number of steam-hammers was 71, viz: 2 of 2 cwt. each, 1 of 3 cwt., 2 of 4 cwt. each, 1 of 7 cwt, 5 of 8 cwt. each, 3 of 10 cwt. each, 1 of 12 cwt., 7 of 15 cwt. each, 8 of 20 cwt. each, 18 of 30 cwt. each, 2 of 60 cwt. each, 1 of 65 cwt., 6 of 70 cwt. each, 2 of 75 cwt. each, 3 of 100 cwt. each, 4 of 110 cwt. each, 1 of 140 cwt., 1 of 150 cwt., 1 of 200 cwt. 1 of 400 cwt., 1 of 1,000 cwt.

Of steam-engines there were 286, viz: 3 of 2 horse-power each, 57 of 4 horse-power each, 46 of 6 horse-power each, 16 of 8 horse-power each, 17 of 10 horse-power each, 6 of 12 horse-power each, 1 of 13 horse-power, 4 of 14 horse-power each, 38 of 16 horse-power each, 4 of 18 horse-power each, 21 of 20 horse-power each, 16 of 23 horse-power each, 3 of 25 horse-power each, 22 of 30 horse-power each, 5 of 35 horse-power each, 2 of 40 horse-power each, 4 of 45 horse-power each, 4 of 60 horse-



FIGS. 214 and 215.—Krupp's Cast-Steel Works, Essen, Prussia.

power each, 2 of 80 horse-power each, 3 of 100 horse-power each, 1 of 120 horse-power, 5 of 150 horse-power each, 1 of 200 horse-power, 1 of 500 horse-power, 3 of 800 horse-power each, 1 of 1,000 horse-power, representing, altogether, nearly 10,000 horse-power.

Of machine-tools there were 1,056, viz: 362 turning-lathes, 82 shaping-machines, 195 boring-machines, 107 planing-machines, 42 punching and grooving machines, 32 presses, 63 grinding-machines, 31 burnishing and polishing machines, 142 other machines of different kinds.

In the year 1872 there were consumed 500,000 tons of coal, 125,000 tons of coke, 113,000,000 cubic feet of water, which was supplied from several water-works, 155,000,000 cubic feet of gas, supplied from the gas-works of the establishment to 16,500 burners. The works are connected with the "Cologne-Minden," "Bergisch-Märkesch," and the "Rhenish" lines of railroad.

To facilitate the traffic about the works there are:

(*a*) About twenty-four miles of railroad, with 180 sidings and 39 turn-tables, on which run 12 tank-locomotives, each of about 16 inches diameter of cylinder, and 530 cars. Six more locomotives are in course of construction.

(*b*) About ten miles of railway of 30 inches gauge, with 147 sidings and 65 turn-tables. The traffic on these railways is carried on by means of horses, and by 3 locomotives of 6 inches diameter of cylinder, and 270 cars. Four other locomotives are in course of construction.

The carriage department comprises 272 cars and 191 horses, of which 60 or 80 are supplied by contractors.

To facilitate communication between the several workshops, there are 30 telegraph-stations.

A permanent fire-brigade, consisting of 70 men, has been instituted, who perform at the same time police-duty. There are also 166 watchmen.

The general supply-stores, under control of the firm, supply to voluntary purchasers, *i. e.* to those belonging to the works, for cash, provisions, clothing, drapery, boots, &c., at cost-price. The receipts at the different stores amount to about £11,000 ($65,000) monthly, and are continually increasing.

Under this head are also to be enumerated: 1 hotel, 3 beer-houses, 1 seltzer-water manufactory, 1 flour-mill, and 1 bakery, with 2 steam-engines, producing at an average 85 tons of bread monthly.

Of the dwellings for the officers and workmen, there are for the former 206, for the latter 2,948, either occupied or in course of construction. There are now living in these houses, the number of which is being rapidly increased, more than 8,000 individuals. The existing boarding-houses offer board and lodging to 2,500 unmarried workmen, and other houses of the same description are now in course of construction for the accommodation of 1,600 more.

The arrangements for the accommodation of the sick consist of one hospital containing 100 beds, and one epidemic-hospital with 120 beds, all under the supervision of physicians especially engaged for the purpose.

A sick, burial, and pension fund has been instituted for all those who receive wages. The firm contributes to this fund half the amount of the contributions paid in by workmen, and is also at the expense of providing pensions and support for those who have been rendered unfit for work in their service, and for the widows of workmen. The total receipts in the year 1872 amounted to £16,000, ($80,000,) the expenditure to £12,500, ($62,500,) and the capital in hand at the beginning of the year 1873 to £19,348, ($96,740.)

From another fund, members receive for their families free medical treatment on an annual payment of 3 shillings, (25 cents.)

The firm has a chemical laboratory, a photographic, a lithographic, and a printing and book-binding establishment. In the printing-office there are two steam and four hand presses in operation.

361. Besides the cast-steel works, near Essen, Friedrich Krupp possesses large mining and smelting establishments, which render the works independent of fluctuations in prices, and secure a regular and uniform supply of the best raw material. This comprises:

1. The administration of the Krupp mines:

(*a*) Coal-pits:

(1.) Pit "Graf Buest;"
(2.) Pit "Ernestine;"
(3.) Pit "Friedrich Ernestine;"
(4.) Pit "Hannover;"

and one-third of the "Humboldt and Diergardt concessions," on the left bank of the Rhine.

(*b*) The iron-ore mines:

(1.) In the mining-districts "Kirchen," "Daaden," "Siegburg," "Hamm," and "Neuwied," 64 mines, (Nos. 1 to 64.)
(2.) In the mining-districts "Wetzlar," "Weilburg," "Dietz," "Oberhessen," "Rheinhessen," and "Dillenburg," 294 mines, (Nos. 65 to 358.)
(3.) In the mining-districts "Hamm on the Sieg," "Wied," "Unkel," "Coblenz," and "Runderoth," 56 mines, (Nos. 359 to 414.)

Total number of mines 414, underlying an area of more than 239,200,000 square yards.

The firm possesses important grants of excellent iron-ore beds in North Spain, whence it is intended to import annually 300,000 tons of ore for the production of cast steel. To facilitate importation, a railway in Spain, nearly eight miles long, and several steamers are already in course of construction.

2. The Administration of Krupp's Smelting-Works controls:

(*a*) The Sayner and Oberhammer Smelting-Works, containing two blast-furnaces, one of them using charcoal as fuel. Together they produce daily about 20 tons of "spiegeleisen" and "charcoal spiegeleisen." An iron-foundry and a machine-manufactory are connected with the "Sayner" Works.

(*b*) The Mulhofer Smelting-Works, on the Rhine, connected by a branch line with the Rhenish Railway, terminating at the Engers Station. They contain four blast-furnaces (three of them of the latest Scotch style of construction) with pneumatic lifts. Each of them produces daily about 45 tons of spiegel, bessemer, and refined iron.

(*c*.) The Hermann's Smelting-Works, on the Rhine near Neuwied, also connected by a branch-line with the Rhenish Railway, has at present only one blast-furnace in operation; two others are, however, in course of construction.

(*d*.) The Bendorf Smelting-Works, with one blast-furnace of an older style, are not in operation.

(*e*.) The Johannes Smelting-Works, formerly the property of the German-Dutch Joint Stock Company for Smelting and Mining, near Duisburg, on the Rhine, produce daily, in four blast-furnaces, from 140 to 160 tons. The construction of six more furnaces has been commenced, and these works are connected with the Railway "Rhenish" and the "Bergisch-Markisch."

These works have also 140 coke-ovens in operation, and 120 more in course of construction.

Krupp's Smelting-Works produce, from 11 blast furnaces, nearly 10,000 tons of pig-iron per month.

362. An idea of the character of the work which is done at Essen is best shown by the following classified and condensed, but still quite complete, description of the objects exhibited at Vienna:

(1.) A crucible cast-steel block, (1,800 crucibles were used, each containing about 60 pounds,) 54 inches diameter of octagonal section, weighing 52,500 kilograms, (52½ tons.)

This casting, originally cylindrical, was reduced to the octagonal form by forging under a 50-ton hammer, to illustrate the malleability of the material. Cuts were made in four different places, while red-hot, to show, when broken off afterward, the density and soundness of the cast-steel. This block, of gun-metal quality, was intended for the body of a gun of 37 centimeters (14 inches) caliber, and was to be given the required form by additional forging.

All articles produced in the establishment, with exception of disk-wheels and frogs, which are cast in molds, are forged and wrought from similar castings of circular cross-section.

(2.) A straight locomotive-axle of crucible cast-steel in the forged state, (pattern of the Northeastern Railway of Switzerland.)

(3.) A forged tender-axle of crucible cast steel, (pattern of the same railway.) The body of this axle was forged complete under the hammer, and required no further working.

(4.) Six carriage-axles of crucible cast steel, forged to the dimensions agreed upon by the German railways.

Production in 1872 of unmounted axles, in the forged and finished state, 16,450.

The first extensive trials with Krupp's cast-steel axles were made in the year 1850, at Borsig's Works, Berlin, by a commission appointed at a meeting of German railway engineers, (pamphlet by Landbaumeister Dihm, Berlin, 1850, printed by J. Petsch.) Although the trials were very favorable, Krupp's cast-steel axles were not generally adopted until the years 1861 and 1862. The production increased rapidly, however, so that the firm supplied in 1865 more than 11,000, while the supply during 1872 exceeded 16,000 axles.

(5.) Two unwelded rings of crucible cast steel, forged from solid blocks by punching a hole in the middle and then driving them out under a hammer.

Railway-tires are given the required dimensions and sections by rolling such rings.

(6.) Two samples of tires, rolled and complete ready for turning; also, one tire ready-turned. Production of 1872, more than 45,000 tires.

Up to the year 1853, only forged-iron and homogeneous-iron tires were manufactured. Krupp's establishment is claimed to have been the first to introduce the unwelded cast-steel tires for use on railroads, and to have caused them to be generally adopted. Since the expiration of their patent of 1853, this method of manufacture has, in principle, been imitated by all works manufacturing cast-steel tires.

(7.) Two unwelded angle-rings of crucible cast steel for steam-boilers, made in the same manner as the tires.

(8.) Two coupling-rods and two connecting-rods forged from crucible cast steel. Pieces of machinery of this description are supplied by the works in the forged state only.

(9.) Four piston-rods forged from crucible cast steel, (pattern of the Central Railway in Switzerland.)

(10.) Two slide-bars of crucible cast steel, in the forged state.

(11.) Two pistons, forged from crucible cast steel, (pattern of the Niederschlesisch-Märkisch Railway.)

(12.) Two locomotive crank-axles of crucible cast steel, one with single and one with double bearings. Both axles are in the finished state. Those crank-axles which were supplied to the French-Orleans Railway during 1857, 1858, and 1859, had, up to 1873, run over 500,000 kilometers, (312,000 miles,) and were still in good working order.

(13.) A locomotive eccentric crank, and one driving-wheel crank, both of crucible cast steel, in the finished state. These pieces are supplied by the works in a rough, or turned, or in a finished state.

(14.) A set of locomotive and tender axles, (pattern for engines CIV of the Northeastern Railway in Switzerland,) consisting of—

(*a*) One driving-axle of crucible cast steel, fitted with tires, cranks of same material, spoke-wheels of wrought iron, and cast-iron counterweights. Weight, 2,160 kilograms, (about 43 cwt., or two tons.)

(*b*) Two coupling-axles of crucible cast-steel, fitted with tires and crank-pins of the same material, spoke-wheels of wrought iron, and cast-iron counterweights. Weight of each, 1,900 kilograms, (about 38 cwt.)

(*c*) Two tender-axles of crucible cast steel, body forged, fitted with tires of same material, and spoke-wheels of wrought iron. Weight of each, 1,200 kilograms, (about 24 cwt.)

Production in 1872 of complete sets of locomotive and tender axles, 475.

(15.) Two carriage-axles of crucible cast steel, body forged, fitted with tires of same material, and spoke-wheels of wrought iron. Weight of each, 950 kilograms, (about 19 cwt.) Axles and tires of the dimensions approved by the German railways.

Production in 1872, 4,650 sets.

(16.) Two carriage-axles of crucible cast steel, fitted with disk-wheels, cast in molds of same material. Weight of each, 1,000 kilograms, (about 20 cwt.)

Production in 1872, 4,340 sets.

(17.) A collection of spring-steel fractures, and cross-sections of spring-steel. This steel is supplied in bars of any section, not less than 10 millimeters thick and 65 millimeters wide.

Production in 1872, 3,000,000 kilograms, (about 3,000 tons.)

See fractures and cross-section under No. 26.

(18.) A collection of cast-steel springs for locomotives, tenders, and carriages.

(*a*) Two locomotive-springs, with 10 flat leaves, welded links, and bored bolt-holes; two with 14 flat leaves and welded, bored, and reamed bolt-holes.

(*b*) Several car-springs, with flat leaves and rolled eyes.

Production in 1872, 38,600 springs.

(19.) A reversible double crossing, or frog, of crucible cast-steel, cast in a mold, and ready to be laid down. (Pattern of the "Cologne-Minden" Railway.) These "frogs" have been introduced on many German and transatlantic railways.

(20.) Bessemer steel-rails. The manufacture of these rails was illustrated by a Bessemer casting, from which octagonal blocks were forged, as shown by exhibited samples. These blocks are given, by rolling, the required form for rails, are cut off according to weight, and rolled to the prescribed section. Two rails rolled in this manner, the ends of which were not cut off, were exhibited. Several rails were ready cut and punched according to the "Cologne-Minden," Section V.

The annual production of steel rails increased from 100 tons, in the first year, to 50,000 tons in 1872. This increase is, no doubt, one of the best proofs of the favorable results obtained from the use of steel rails on railroads, and these rails are now very largely introduced.

Besides the manufacture of steel rails for ordinary railroads, the manufacture of smaller sections, from 11 to 22 pounds per yard, for mining-purposes, has also considerably increased.

Production in 1872, 2,000 tons.

A collection of rail-fractures of different kinds was also shown.

(21.) Two switches of Bessemer steel, (section of the "Oberschlesisch and Niederschlesisch-Märkisch" Railroad,) planed as supplied by the works in the finished state.

(22.) A double crank-shaft, of crucible cast steel, forged from a solid block, and finished for a transatlantic steamer—weight, 9,000 kilograms; length, 7,650 meters; diameter, 0.38 meters.

(23.) A trunnion-hoop, unwelded, of crucible cast steel, in the forged state.

(24.) Two pressed sides for field-gun carriages, of cast steel, 6 millimeters and 10 millimeters thick.

(25.) Rolling-mill machinery. The rolls exhibited illustrate the most usual forms and dimensions used in this, which is one of their oldest branches of manufacturing.

(26.) A collection of fractures of hardened tool-steel, as well as various other fractures of manufactured articles, such as axles, tires, and frogs, and disk-wheels, and mint-dies with polished surface.

(27.) A series of exhibits of various classes of ore, pig-iron, and pig "steel-iron," from the mines and smelting-works of the firm, used in the manufacture of steel.

363. The ORDNANCE made by Krupp is all manufactured from crucible cast steel of a quality especially adapted to this purpose.

All these guns are breech-loading, and have Krupp's breech-piece.

The naval and coast gun-carriages are generally manufactured from wrought-iron; only special parts, such as the axles, cylinders, and piston-rods of the hydraulic buffer and the slide-rollers of the coast-gun carriages being made of cast steel. Cast iron is only used for small truck-wheels. There were exhibited—

(28.) A 30½-cm. (30½ centimeters diameter) gun on coast-carriage.

Caliber 305 millimeters, (12 inches.)

Length of gun, 6.7 meters.

Length of bore, 5.77 meters.

Weight of gun with wedge, 36,600 kilograms,* (80,500 pounds.)

The gun has 72 parallel grooves, with 4.5 millimeters width of lands, and a uniform twist of 21.79 meters in pitch.

Weight of charged steel shell, 296 kilograms.

Weight of charge, (prism-powder,) 60 kilograms.

Initial velocity, 465 meters.

Weight of charged common shell, 257 kilograms.

Weight of charge, (prism-powder) 50 kilograms.

Initial velocity, 460 meters.

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* The kilogram = 2.2 pounds; the meter = 3.28 feet, = 39.38 inches; the centimeter = 0.0328 foot, = .3928 inch; the millimeter = 0.00328 foot, = 0.03928 inch.

The carriage is intended for earth parapets of 1.9 meters height, and has a height of 2.380 meters. To check the recoil, a hydraulic buffer is used.

The projectile is lifted by means of a movable crane with windlass, which is arranged on the right-hand side of the slide.

The elevation (+17° – 7°) is taken by means of a toothed arc on the upper part of the carriage. For training, the end of the slide is provided with a chain-gear.

By this apparatus the gun can be very easily and quickly handled.

To run in the gun, a rope windlass may be placed, if necessary, on each side of the slide at the rear.

	Kilograms.
Weight of carriage	5,650
Weight of slide	15,350
Total weight	21,000

This gun, and all of those exhibited, in fact, was a magnificent mass of metal, beautifully finished, conveniently arranged, and in every respect a splendid piece of work.

(29.) A 28-centimeter howitzer on coast-carriage. The gun is constructed to be placed in coast-batteries.

Caliber, 280 millimeters.

Length of gun, 3.200 meters.

Length of bore, 2.520 meters.

Weight, with wedge, 10,000 kilograms.

Preponderance, 0.

This gun has 72 parallel grooves, with 4.5 millimeters width of lands, and a uniform twist of 11.2 meters.

Weight of charged common shell, 199 kilograms.

Maximum weight of charge, 20 kilograms.

The carriage of the gun admits of an elevation of 75°.

The carriage differs from the coast-gun carriages principally in that the whole of the under face of the slide lies in the platform on firing, so as to extend the impact of recoil over a larger surface. For training, the slide is placed upon rollers, for which reason the rear slide-trucks are put on eccentric axles.

The projectile-crane, training-gear, hydraulic buffer, and self-acting running-out apparatus are the same as in the other coast-gun carriages. The elevating gear is also similarly constructed.

Weight of the whole carriage, 9,220 kilograms.

Height, 1.675 meters.

(30.) A short 26-centimeter ship-gun on battery-carriage.

Caliber, 260 millimeters.

Length, 5.2 meters.

Length of bore, 4.420 meters.

Weight of gun, with wedge, 18,000 kilograms.

Preponderance, 0.

This gun has 64 parallel grooves, with 4.25 millimeters width of lands, and a uniform twist of 18.2 meters.

Weight of charged steel shell, 184 kilograms.

Weight of charge, (prism-powder,) 37.5 kilograms.

Initial velocity, 450 meters.

Weight of charged common shell, 159 kilograms.

Weight of charge, (prism-powder,) 30 kilograms.

This gun has a carriage for use in a broadside-battery of iron-clads. The carriage differs from former ship-carriages for similar purposes principally in that the hydraulic buffer and apparatus for self-acting running out are similar to those of coast-gun carriages. The hydraulic buffer is so arranged that the gun, with the upper part of the carriage, can be held on any part of the slide.

The training is effected by a toothed wheel, which works into a toothed racer in the deck, and is moved by a worm-wheel so as to dispense with brakes to retain the gun in the required direction. For elevation, there is arranged on both sides of the gun a toothed elevating-arc; both are, however, moved simultaneously from the left side of the carriage by a hand-wheel. In order to relieve the ship's side in firing, the recoil is partially received by ribs on the upper face of the deck-racers and by a strong hook which ties down the fore part of the slide.

Total weight of carriage is 8,756 kilograms.

Height, 1.220 meters.

(31.) A long 24-centimeter gun on battery-carriage for casemate ships.

Caliber, 235.4 millimeters.

Length of gun, 5.23 meters.

Length of bore, 4.54 meters.

Weight of gun, 15.500 kilograms.

Preponderance, 0.

This gun has 32 grooves, with a width of lands of 3.9 millimeters at breech and 7.85 millimeters at the muzzle. The twist is uniform, and of 16.48 meters pitch.

Weight of charged steel shell, 135 kilograms.

Weight of charge, (prism-powder,) 24 kilograms.

Initial velocity, 430 meters (2,296 feet) per second.

Weight of charged common shell, 118.5 kilograms.

Weight of charge, 20 kilograms.

Initial velocity, 424 meters per second.

The gun is mounted on a battery-carriage for casemate ships. Being situated in one of the obtuse angles of the casemate, so as to be capable of firing through a broadside and a bow or stern port, it was necessary to make arrangements for a change from the one to another port. This is done by means of a turn-table, on which the gun rests supported by the middle slides and the rear slide-rollers, after the fore slide-rollers have been lifted by an hydraulic lifting-jack which is fixed under the slide for this purpose. To facilitate the unshackling of the pivot-bar when changing ports, it is divided, and at the joint an easily-removable bolt is put in.

To check the recoil, the carriage is provided with an adjustable plate-compressor. A running-in-and-out gear, of chain, is applied on both sides of the slide-end. For training, the pinion of the cog-racer is moved by the same cranks which are used for this chain-gear.

The elevation is taken by means of a cogged elevating-arc.

	Kilograms.
Weight of carriage	2, 344
Weight of slide	5, 466
Total weight	7, 810

Height, 1,195 meters.

(32.) A long 21-centimeter gun on coast-carriage.

Caliber, 209.3 millimeters.

Length of gun, 4.708 meters.

Length of bore, 4.106 meters.

Weight of gun, 10,000 kilograms.

Preponderance, 0.

This gun has 30 grooves, with 3.4 millimeters width of lands at breech and of 7.3 millimeters at the muzzle. The twist is uniform and of 14.23 meters pitch.

Weight of charged steel shell, 95 kilograms.

Weight of charge, (prism-powder,) 17 kilograms.

Initial velocity, 430 meters per second.

Weight of charged common shell, 79 kilograms.

Weight of charge, 14 kilograms.

Initial velocity, 430 meters per second.

The gun is mounted on a coast-carriage of a description similar to that of the 30½-centimeter gun. Height, 2.015 meters.

	Kilograms.
Weight of carriage	2,090
Weight of slide	5,110
Total weight	7,200

(33.) A 21-centimeter siege-gun, with slide-carriage.

Caliber, 209.3 millimeters.

Length of gun, 3.400 meters.

Length of bore, 2.910 meters.

Weight of gun, with wedge, 3,900 kilograms.

Preponderance, 0.

The gun has 30 grooves, with 3.7 millimeters width of lands at the breech and of 7.5 millimeters width at the muzzle. The pitch of rifling is 12.36 meters.

Weight of charged common shell, 79 kilograms.

Weight of charge, (prism-powder,) 6.5 kilograms.

Initial velocity, 300 meters per second.

The carriage for this gun is a short slide-carriage, in all essential points similar to the coast-carriages. The slide, when in battery, rests in front on the pivot-block, behind on two rollers which can be moved, for the purpose of training, by means of handspikes. The elevating-arc admits of 27° elevation and 6° inclination. The crane, hydraulic buffer, &c., are similar to those of the coast-carriages. This gun is properly arranged for transport. For this purpose, a strong axle, with large wheels, is placed in the axle-supports, after the gun and carriage have been run in on the slide; then the forward end of the slide is raised by means of a lifting-apparatus which is permanently fixed on the slide. This consists of a screw, with worm-wheel gearing. Finally the rear end of the platform is limbered up. The rear wheels have a diameter of 2.046 meters and a breadth of 0.180 meter in the rim. The distribution of the weight resting on hind and fore wheels is in the proportion of 4 to 1. To lighten the transport-wagon, the slide-rollers may be carried separately. For transport by rail, the limbered-up carriage can be easily placed on a 10-ton freight-car. The bed, made of oak beams, and provided with pivot-block and racer, can be carried on an ordinary freight-car. As soon as the gun has been carried to its proper place over the bed in the battery, it is unlimbered and the rear slide-rollers are then lowered down on the racer by means of a windlass. The slide is afterward let down in front upon the pivot-block and the transport axle and wheels are removed.

Height of battery, 1.9 meters.

	Kilograms.
Weight of carriage	922
Weight of slide	1,728
Total weight	2,650

The limbered-up gun has a total weight of 8,160 kilograms.

The bed complete weighs 2,080 kilograms.

(34.) A long 17-centimeter gun, on upper-deck carriage.

Caliber, 172.6 millimeters.

Length of gun, 4.250 meters.

Length of bore, 3.780 meters.

Weight of gun, with wedge, 5,600 kilograms.

Preponderance, 0.

The gun has 48 parallel grooves, with 3.5 millimeters width of lands, and a uniform twist of 11.2 meters.

Weight of charged steel shell, 55 kilograms.

Weight of charge, (prism-powder,) 10 kilograms.

Initial velocity, 460 meters per second.

Weight of charged common shell, 45 kilograms.

Weight of charge, (prism-powder,) 10 kilograms.

Initial velocity, 465 meters per second.

The upper-deck carriage for this gun is to be placed in the bow or stern of an iron-clad, and so arranged as to be moved easily and quickly into a rear position. To check the recoil, a plate compressor is used. For training, the slide, which usually rests on the supports, is placed on the rollers, for which purpose the rear slide-rollers are mounted eccentrically.

Height, 1.020 meters.

	Kilograms.
Weight of carriage	1,255
Weight of slide	2,235
Total weight	3,490

(35.) A 15-centimeter siege-gun on wheel-carriage.

Caliber, 149.1 millimeters.

Length of gun, 3.44 meters.

Length of bore, 3.040 meters.

Weight of gun, with wedge, 3,000 kilograms.

Preponderance 1 meter from the trunnion, 25 kilograms.

This gun has 36 grooves, with 3 millimeters width of lands at the breech and 5.5 millimeters at the muzzle.

The pitch of the twist of the rifling is 9.7 meters.

Weight of charge, common shell, 28 kilograms.

Weight of charge, (prism-powder,) 6 kilograms.

Initial velocity, 470 meters.

The carriage of this gun is constructed as a wheel-carriage. The brackets are made of plates and angle-iron. The elevating-screw admits of 35° elevation and of 5° inclination. The hydraulic buffer is a peculiarity in this carriage. At the discharge this reduces the recoil to 1 meter or less. The buffer-cylinder can be moved vertically, being fastened to the brackets at one-third of their length from behind. The piston-rod can be moved vertically and horizontally by means of a pivot-bolt connected with an anchor which is partly imbedded in the parapet. Height, 1.830 meters; weight of carriage, 1,845 kilograms.

(36.) A long 15-centimeter gun on ship carriage.

Caliber, 149.1 millimeters.

Length of gun, 3.85 meters.

Length of bore, 3.43 meters.

Weight of gun, 4,000 kilograms.

Preponderance at the commencement of the rounding of the wedge, 75 kilograms.

The gun has 48 parallel grooves, with 3 millimeters width of lands and 9.7 meters pitch of rifling.

Weight of charged steel shell, 35 kilograms.

Weight of charge, (prism-powder,) 8 kilograms.

Initial velocity, 460 meters per second.

Weight of charged common shell, 28 kilograms.

Weight of charge, 6.5 kilograms.

Initial velocity, 465 meters per second.

The carriage of this gun is made for broadside use. It is a slide-carriage. To check the recoil a plate-compressor is used, and a breeching is attached as reserve. The elevation is effected by a toothed elevating-arc, and the training by means of tackles, for which side-eyes are provided on the rear end of the slide. The slide usually rests upon supports on the racers; for training, it is lifted upon the rollers.

Height, 0.960 meter.

	Kilograms.
Weight of carriage	1,505
Weight of slide	935
Total weight	2,440

(37.) A 12-centimeter gun on ship-carriage.

Caliber, 120.3 millimeters.

Length of gun, 2.925 meters.

Length of bore, 2.602 meters.

Weight of gun, with wedge, 1,400 kilograms.

Preponderance, 100 kilograms.

The gun has 18 grooves, their breadth increasing toward the breech, with 2.5 millimeters width of lands at the breech and 6.5 millimeters at the muzzle. The pitch of twist is 842 meters.

Weight of charged steel shell, 15.5 kilograms.

Weight of charge, (large-grained powder,) 3.5 kilograms.

Initial velocity, 450 meters per second.

Weight of charged common shell, 15.5 kilograms.

Weight of charge, (large-grained powder,) 3 kilograms.

Initial velocity, 450 meters per second.

The carriage for this gun is a wheel-carriage, constructed for the main or upper deck of small vessels. To check the recoil, a hydraulic buffer-cylinder, movable vertically and horizontally, hangs on the pivot-bolts. The piston-rod is fastened to the carriage. A strong breeching is provided as a reserve. The carriage rests usually on four rollers. For training, the rear rollers, which are mounted eccentrically, are lifted, and the weight is thus transferred to a training-roller.

The elevation is taken by means of a toothed elevating-arc, which admits of a motion of 15° and 10° in elevation and depression, respectively.

Height, 0.900 meters.

Weight of carriage, 895 kilograms.

(38.) A 9-centimeter field-gun, with carriage.

Caliber, 91.5 millimeters.

Length of gun, 2.040 meters.

Length of bore, 1.819 meters.

Weight of gun, with wedge, 425 kilograms.

Preponderance, 50 kilograms.

The gun has 16 grooves, with 2.5 millimeters width of lands at the breech and 6.5 millimeters at the muzzle. The rifling has 4.53 meters pitch.

Weight of charged shell, 6.9 kilograms.

Weight of charge, (cannon-powder,) 0.6 kilograms.

Initial velocity, 322 meters per second.

The gun-carriage has riveted wrought-iron brackets. Weight of carriage, (without accessories,) 546 kilograms. The elevating-screw admits of an elevation of 15° and of a depression of 8°.

(39.) An 8-centimeter field-gun, with carriage.

Caliber, 78.5 millimeters.

Length of gun, 1.935 meters.

Length of bore, 1.728 meters.

Weight of gun, 295 kilograms.

Preponderance, 70 kilograms.

This gun has 12 grooves, with 2.5 millimeters width of lands at breech and 6.5 millimeters at the muzzle. The rifling has 3.62 meters pitch.

Weight of charged shell, 4.3 kilograms.

Weight of charge, (cannon-powder,) 0.5 kilogram.

Initial velocity, 357 meters per second.

Weight of carriage, (without accessories,) 460 kilograms. The elevating-screw admits of $13\frac{15}{16}$° elevation and 8° inclination.

(46.) A 6-centimeter mountain-gun, on carriage.

Caliber, 60 millimeters.

Length of gun, 1.250 meters.

Length of bore, 1.130 meters.

Weight of gun, with wedge, 107 kilograms.

Preponderance, 14 kilograms.

This gun has 18 parallel grooves, with 3 millimeters width of lands and 2.10 meters of pitch of rifling.

Weight of charged shell, 2.3 kilograms.

Weight of charge, 0.2 kilogram.

Initial velocity, 300 meters per second.

The carriage has wrought-iron brackets, cast-steel axles, and wooden wheels. On the naves of the axles there are conical friction-brakes.

Weight of carriage, 109 kilograms; height, 0.660 meter.

The elevating-screw admits of 21° elevation and of 10° depression.

(41.) Ammunition:

(*a*) Shells, forged of crucible cast steel, for each of the exhibited guns, both whole and cut to exhibit the cross-section.

(*b*) Common cast-iron shells for all exhibited guns, some cut to show cross-sections, and all with complete percussion-fuses.

(*c*) Models of cartridges and of prismatic powder.

The specific gravity of the prismatic powder is, for the 26-centimeter, 28-centimeter, and 30½-centimeter guns, from 1.72 to 1.76; for those of smaller calibers, it ranges from 1.62 to 1.66.

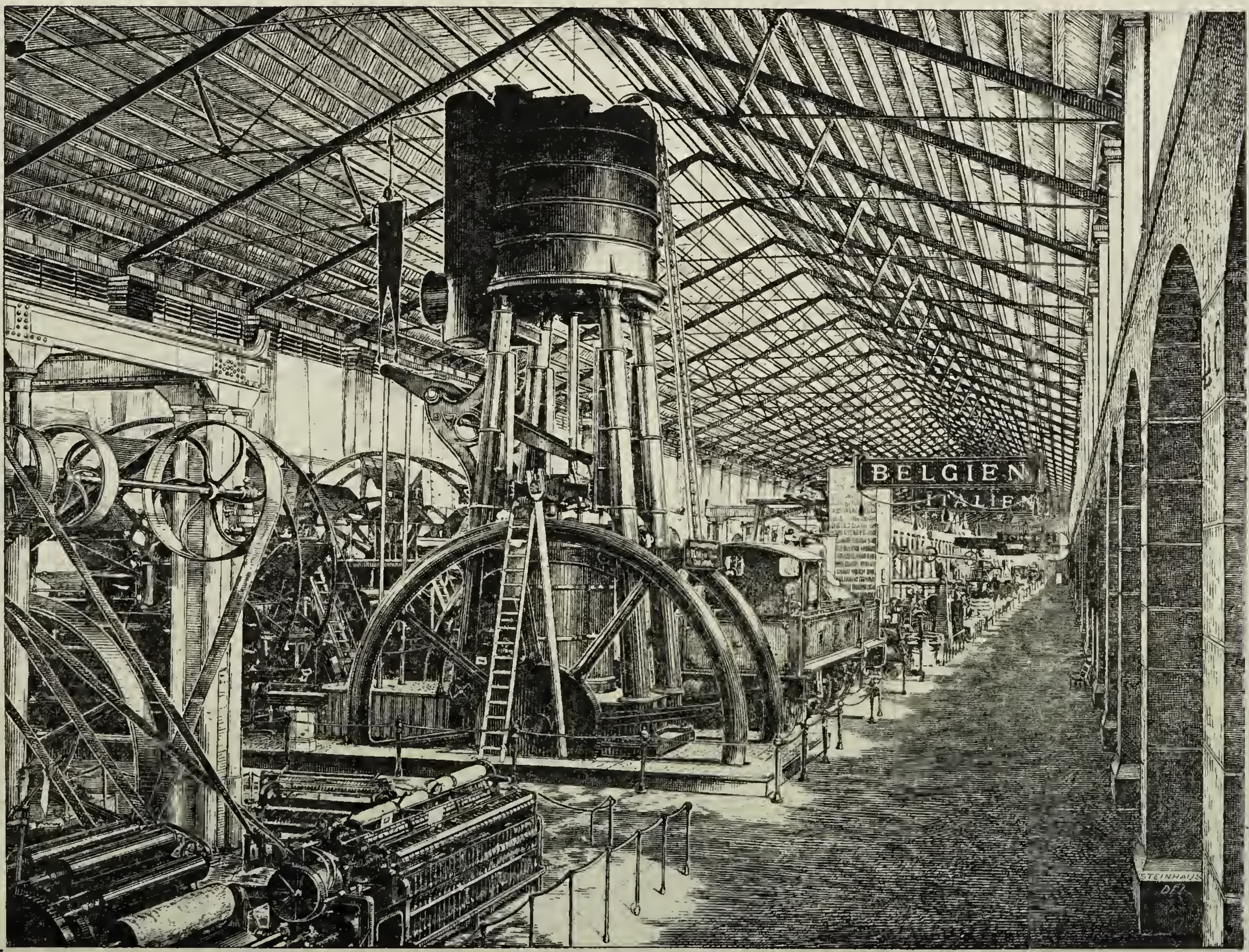
364. The variety as well as the magnitude of the work done at Essen is well shown by the preceding description.

It should be remarked that the general construction of these guns is similar to that of the British Woolwich gun, except that the Prussian gun is breech-loading.

The description just given of this remarkable class of productions of the Krupp establishment is particularly valuable as exhibiting the peculiarities of a practice in the construction of artillery which is very largely introduced in Europe, especially in Prussia and the other German states and in Russia, and which is competing with those other characteristic forms adopted in Great Britain and in the United States.

The compressing-apparatus and friction-gear are in many instances similar to those introduced by Capt. John Ericsson, and used on nearly all the heavy ordnance of the United States Navy and of the navy of Spain. It has also been closely imitated in the Scott gun-carriages used in the British navy.

Vienna Exhibition 1873. Machinery etc.



American Photo-Lithographic Co. N.Y. (Osborne's Process).

Fig. 216

CHAPTER IV.

BELGIAN AND FRENCH MANUFACTURING ESTABLISHMENTS AND TECHNICAL SCHOOLS.

BELGIUM.—THE SERAING WORKS OF THE SOCIÉTÉ COCKERILL; HISTORY OF THE COCKERILL WORKS—EXTENT—PRODUCTION; THE COCKERILL EXHIBIT AT VIENNA; BELGIAN MANUFACTURES—HISTORY—PRODUCTION; CONDITION OF WORKING-PEOPLE.

FRANCE.—PARIS; CONSERVATOIRE DES ARTS ET METIERS—ITS HISTORY; WORKS OF MM. SCHNEIDER & CO., AT LE CREUSOT—THEIR HISTORY—EXTENT OF THE WORKS AND PRODUCTION; LYONS; THE PERMANENT INDUSTRIAL EXHIBITION; CAIL & CO.'S WORKS, AT PARIS.

365. BELGIUM.—Seraing is situated near the city of Liege, a city of over 100,000 inhabitants, which has long been celebrated for the extent of its manufacturing industries, and has been frequently called the "Birmingham of Belgium." This has prospered as a manufacturing district for centuries, and at an early date the bishops of Liege were sufficiently powerful to raise a considerable force and to maintain themselves against the attacks of all enemies, whether nobles or citizens.

The town of Seraing and the great manufacturing establishment of the "*Société Cockerill*" now occupies the site of the residence and landed property of the bishops. These works are the only very extensive works of the kind in this district, and are the largest in Belgium, and, with but few exceptions, have no equals in size in the world.

The first blast-furnace erected here was put up by the English founders, the Brothers Cockerill, in 1826. The establishment now produces annually 350,000 tons of coal, from four collieries; its thirty iron-mines yield a hundred and fifty thousand tons of ore annually; there are nine blast-furnaces—four of which were at the time of our visit unfinished—and large Bessemer works and founderies. The furnaces in blast yield, as an average product, about 60,000 tons of foundery and forge iron, and those in course of erection are intended to supply dark iron to the Bessemer works. The founderies produce 5,000 tons of iron and brass castings, and the rolling-mills turn out between 40,000 and 50,000 tons of rails and large quantities of other rolled metal per year.

The ten converters in the steel-works were stated to yield 17,000 tons of steel per year; the forges can make nearly 2,000 tons of forgings, and the plate-iron-working shops 6,000 tons of bridges and steam-boilers per annum.

The establishment has a ship-building yard at Antwerp.

At Seraing the works cover two hundred acres of land, on the property formerly belonging to the bishops of Liege; the number of workmen employed is between nine and ten thousand, who receive about $2,000,000 annually as wages. The two hundred and fifty steam-engines and the numerous furnaces consume 350,000 tons of coal per year, and sales amount to between $5,000,000 and $6,000,000.

The coal raised from the mines directly at the works is of good quality, and its excellence and the convenience and cheapness of this deposit of fuel constitute the principal element of the success of the establishment. The coal cokes well, producing a coke of considerable strength and hardness, clean, free-burning, and unusually pure.

Several Appold kilns are used in coking, which were said to do good work, and a considerable amount of coal is also still coked in the common coke-oven. This coke is not much inferior to those which have made the English Yorkshire districts so successful.

The iron made here, in the blast-furnaces above referred to, is of good quality, and answers well for the Bessemer works. The ores are obtained both from this district and from Spain and Great Britain. The castings made from this iron are smooth, of good color and grain, and are remarkably clean and strong.

All of the refractory material used in the furnaces and founderies is obtained from the immediate neighborhood. There is no necessity of importing either molding-sand or fire-clay, and bricks of fine quality are made on the spot.

The machinery and plate-iron work is well made and usually well proportioned. The material is always excellent, the design generally good, and the fitting and the finish are almost invariably such as would receive commendation from any engineer.

The low cost to the works of Bessemer steel has led to the introduction of that material very extensively into the machinery made here, taking the place not only of iron forgings, but of cast iron in many places. The new Bessemer works now in process of erection will yield a product of low steel amounting to a hundred and fifty tons of metal per day, and its use in construction will then become still more extended.*

The pay of the workmen in the foundery is 75 or 80 cents a day; of puddlers, $1 to $1.50; pattern-makers are given about the same pay as the molders; riveters in the boiler-shops receive the same; machinists are paid about 25 cents more, and foremen in the several shops are paid about $2. The length of the working-day is nominally twelve hours.

366. The following account of the Seraing establishment is based upon the statements furnished to the writer and other members of the International Jury by the proprietors:

The principal establishments of the Cockerill Company are situated at Seraing, six miles from the town of Liege, in the valley of the Meuse, upon the carboniferous formation which runs through that territory. They occupy the estate which was used as a summer residence by the prince-bishops of Liege until the end of the last century.

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* In these works, since completed, the cast iron is run into the converter from the blast-furnace, as at Creusot.

The business of the Cockerill establishments comprises coal and iron mining, the reduction of the ores, the manufacture of cast and wrought iron and steel, the construction of engines, boilers, and machines, and the construction of iron bridges and of iron vessels.

The Cockerill Company is managed by a board composed of five members and a Director-General.

These establishments form eleven special divisions, managed by chief-engineers.

The foundation of the Seraing establishment was the work of John Cockerill, who was an Englishman, born at Haslington, Lancashire, England, August 3, 1790. His father, in 1799, introduced at Liege the construction of machines for wool-spinning, and, after having acquired a large fortune, in 1813 he left his factories to his two sons, James and John.

Coal and iron mining and the smelting of charcoal pig-iron had been practiced, and workshops manufacturing articles of wrought iron had been in existence in the Liege territory for centuries. Beside those engaged in husbandry, the working-class of the country was composed of coal-miners, smelters, blacksmiths, cutlers, nail-makers, and of lock and gun smiths.

In 1817 the Cockerill Brothers bought from the government of the Netherlands the palace of Seraing, and established works for the construction of steam-engines and of machinery for spinning flax, and they afterward erected a flax-spinning mill.

In 1822 John Cockerill came to reside at Seraing, and bought the grant of coal-mines upon which the works now stand, and took proper measures to introduce on the continent the smelting of cast-iron with coke and the fabrication of iron by the English processes.

The business of the factory was then chiefly sustained by the orders of the government. In 1824 steam-engines of 300 horse-power were constructed, under John Cockerill's supervision, for the men-of-war of the country, while the English navy had engines of only 150 horse-power.

In 1826 the first coke blast-furnace, and the furnaces, hammers, and blast-engines, and the engines for the iron-works were employed. The coal-pits, furnished with powerful ventilating and hoisting machinery, were set in operation upon a scale previously unknown.

The first continental railway was decreed by the Belgian government after the revolution of 1830, and the first locomotive was constructed for that railway, in 1834, by the Seraing Works, which soon after supplied all the engines for the beginning of the Belgian net-work of railways.

The Seraing establishment continued to increase rapidly until the demise of John Cockerill, which happened in 1840. It comprised in 1842, at the time of the formation of the joint-stock company established to continue operations:

1st. The grant of coal-mining, with three collieries furnished with all needed ventilating and hoisting engines.

2d. Thirty-seven coke-kilns of large size.

3d. Two blast-furnaces, with "steam bellows" and grants of iron-mines.

4th. A vast iron-foundery and a copper-foundery.

5th. An iron-making establishment, with 35 reverberatory furnaces, 5 sets of rolls, with hammers, steam-engines, and all tools and apparatus required in such works.

6th. An engine and boiler works, containing 144 forge-furnaces, 280 lathes and boring-machines, 200 planing, grooving, tapping, and drilling machines, &c.

There were 2,200 employés and workmen. The driving-engine was of 920 horse-power.

The Seraing establishments had been placed by John Cockerill, in 1829, under the general superintendence of Gustave Pastor, his nephew, and the latter continued in service when the company was formed and until 1866, at which time M. Pastor withdrew, and he was succeeded by M. E. Sadoine, chief engineer of the government navy.

367. The works now comprise:

Coal-mines.—Four collieries, with eight shafts for raising the coal; 24 engines of 900 collective horse-power; 2,400 workmen, (since 1867 women have not worked in the collieries of the company;) annual production of fuel 350,000,000 kilograms, (350,000 tons.)

Coke-furnaces.—Four groups comprising 143 horizontal kilns; 12 groups comprising 216 Appold kilns; 3 crushers and 6 washers; 6 steam-engines, of 168 collective horse-power; 140 workmen. Annual production of coke, 140,000,000 kilograms, (140,000 tons.)

Iron-mines.—Thirty mines, in the Belgian provinces of Liege and Namur, in Luxemburg, and in Spain; 17 engines, 306 horse-power collectively; 800 workmen. Annual production of the mines, 150,000,000 kilograms, (150,000 tons.)

Blast-furnaces.—Five blast-furnaces, with hot-blast apparatus and casting-houses for ordinary casting, yielding 55,000,000 kilograms, (55,000 tons;) 4 blast-furnaces for Bessemer steel pig now building; 15 engines, of 480 collective horse-power; 300 workmen.

Founderies.—Two iron and one copper founderies; 2 workshops for molding; steam-cranes; 1,000,000 kilograms foundery-flasks; 6 engines, of 90 collective horse-power; 280 workmen. Annual production, 5,000,000 kilograms, (5,000 tons.)

Iron-works.—Seventy-five reverberatory furnaces; 12 sets of rolls; 7 hammers; 55 engines, of 1,900 collective horse-power; 1,240 workmen. Annual production in rails, girders, bar and sheet iron, 40,000,000 kilograms, (40,000 tons.)

Steel-works.—Ten Bessemer converters, of from 5 to 7 tons capacity, 6 of which are just erected; 16 reverberatory furnaces; 7 hammers; 4 sets of rolls; 46 engines, of 3,079 collective horse-power; 560 workmen. Annual production in steel, 17,000,000 kilograms, (17,000 tons.)

Forges.—Twelve reverberatory furnaces; 7 hammers; 70 forge-furnaces; 5 engines, of 288 collective horse-power; 200 workmen. Annual production of machinery, 1,500,000 kilograms, (1,500 tons.)

Engine-shops.—Three hundred and sixty-eight lathes, slotters, planers, drills, &c.; 5 machines to forge bolts and nuts; 2 hydraulic presses; traveling cranes, stationary steam-cranes, and others; 20 engines; 1 hammer; 1,400 workmen. Annual production of machines and mechanical apparatus, 7,000,000 kilograms, (7,000 tons.)

Bridge and boiler building.—Fifty-five drilling, planing, &c., machines; 3 hammers; 54 forge-furnaces; 11 engines, of 120 collective horse-power; 510 workmen. Annual production of boilers and of bridges of various kinds, 6,000,000 kilograms, (6,000 tons.)

The Antwerp ship-building yard contains a stock of tools appropriate to a ship-builder's yard, with covered ways, rafts, and boats; ways and slips for launching both sea and river steamers; carpentry and joinery shops, with steam-power; 2 engines, of 15 horse-power, and employs 680 workmen. Annual production, 2,500,000 kilograms (2,500 tons) of iron vessels.

The interior conveyance and forwarding department has in operation 15 locomotive-engines, employed on the junctions of the interior railways, with the north line; employs 420 workmen and 60 horses, 15 of which are in the collieries.

These works cover an area of 200 acres, intersected by 22 kilometers* of railroads of standard gauge, and 12 kilometers of smaller tracks. A basin communicating with the Meuse by a canal and 2 wharves belong to the establishment.

In 1872 there were 8,912 people employed in all the works.

There were 254 steam engines, of 7,834 collective horse-power.

The wages paid annually amount to 8,500,000 francs, ($1,700,000.)

The consumption of fuel amounts to 350,000,000 kilograms, (350,000 tons.)

The production of the divisions is from 25,000,000 to 30,000,090 francs, ($5,000,000 to $6,000,000.)

The establishment owns on the heights of Seraing, and in a very healthy situation, a large infirmary managed by nuns. It contains 85 beds. A special physician is attached to it, and an orphan-asylum, containing at present forty-one children of both sexes, adjoins it.

The establishment has also a dispensary, which delivers medicines gratuitously to persons attached to the works, and to their families.

In each division there is a refectory, furnishing meals to the workmen. Kitchens are added to several of these refectories; and baths are put up at the collieries for the miners.

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* The kilometer is 3,280 feet, about three-fifths of a mile.

A society for relief and pensions has been instituted for the people of the works, and the establishment accords, out of its own funds, temporary relief and pensions to the workmen and employés not concerned in the society, membership in which is not compulsory.

The Seraing Works have constructed (to January 1, 1873,) 2,100 steam-engines, of from 4 up to 600 horse-power, for all known manufacturing purposes; 900 locomotive-engines; 31,540 sets of machinery and of mechanical apparatus, and various pieces of mechanism for manufactories; has done a large amount of repair-work, and has furnished manufactured material for mining, for the reduction of ores, the fabrication of metals, for buildings, sugar-works, plate-glass manufactories, paper-mills, spinning-mills, lattice and suspension bridges, turrets for iron-clads, &c.

The ship-yards at Antwerp and St. Petersburg have built 282 sea and river steamers, yachts, mail-steamships, steam-tugs, pilot-boats, light-ships, dredging-machines, transport ships for passengers and freight, transatlantic steamers and floating-docks for iron-clads.

The Cockerill Company can supply annually 100 locomotives, 70 marine steam-engines from 4 to 1,000 horse-power, and above 1,500 sets of mechanical constructions. It erects complete works, makes special apparatus, does repairs, &c. It can build 6,000 tons of bridges and turn-tables per annum. Sea and river steamers of 5,000 tons burden, British measurement, can be built here.

It was at Liege that Cockerill, senior, established the first manufactory of cotton and woolen machinery on the continent, and at Seraing the first coke blast-furnace and the first puddling-furnace, and afterward the coke-kilns were erected and the making of iron by English methods was commenced.

The first steam-engine and the first locomotive-engine on the continent were constructed at Seraing.

Since 1824 the Cockerill establishments have constructed very powerful steam-engines for the drainage of the collieries of the Liege Valley, where they are still working.

368. At Vienna this great firm exhibited a marine engine of 220 nominal horse-power, built for the Belgian mail service between Ostend and Dover.

The steamers carrying the mail between Belgium and England are remarkable for their great and regular speed, their fine accommodations, and, above all, for their excellent sea-going qualities in bad weather. Their speed, in calm weather, reaches 17 knots (19$\frac{3}{4}$ miles) an hour, and is not exceeded by that of any other channel-steamers. The time on the passage averaged for six months, between Ostend and Dover, 4 hours 4 minutes. This result, it is said, is not inferior to that of the steamers plying between Holyhead and Dublin, which latter are of 2,000 tons burden, and fitted with engines of 750 nominal horse-power.* This speed is due to the fine lines of these ships, to their great power, and to the excellent design and good construction of their engines. The latter have given at the official trials a power of nearly 1,600 horses.

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* Actual horse power not stated, but probably 3,500 to 4,000.

The success of the first of these ships, the "Louise-Marie," which was supplied in 1866 to the Belgian government, induced the government to have seven of these steamers built, without the slightest alteration of design. Six are now running regularly. The engine intended for the seventh was that shown at the Exhibition. All of the principal forgings are of Bessemer steel, from the steel-works of the Cockerill Company.

These ships were built in the ship-yard of the company, at Antwerp; the engines were constructed in the works at Seraing.

The principal dimensions were as follows:

Length on water-line	200 feet
Breadth, extreme	20 feet.
Depth	13¼ feet.
Tonnage, (B. M.)	568 tons.
Tonnage, (net)	505 tons.
Draught	7 feet.

369. BELGIAN MANUFACTURES.—The interesting city of Liege and all the country about it is an exceedingly prosperous and industrious district. It probably is the most active manufacturing district in Continental Europe. All along the road between Liege and Brussels manufacturing villages are thickly distributed, and the whole country is one great manufactory of machinery and "Birmingham wares."

This is one of the earliest of European iron-making districts. It is now well known to have been a seat of manufactures in iron as early as at the time of the Roman occupation, nearly two thousand years ago. It is only two or three years ago that the ruins of several furnaces of the rude form then used were discovered at Lustin, with their charges of fuel and ore still in place.

In building machinery the Belgians are only second to the English, and they have even competed successfully with the latter in some instances in making pumping-machinery for British mines. The Belgian workman has hardly as much energy or tact or skill as the British, but he, nevertheless, does good work, and is persistent and steady.

Belgium has always been noted for its production of some kinds of textiles, of which the best known are the woolens of Ypres, the linens of Flanders, the cloth made at Verviers, the calicoes of Ghent, the carpets of Tourney and Brussels, and the lace of Mechlin and Brabant. The manufactures of porcelain, the Namur cutlery, and the Liege ironwares are scarcely less well known. Flanders and Antwerp almost monopolize the cotton-goods manufacture. Cotton-machinery is largely imported from England, and the higher grades of work-people are not infrequently also English. For hundreds of years these districts have also produced woolen goods, obtaining their woolen in earlier times principally from England, Spain, and Germany, and returning the manufactured material to all the markets of Europe.

370. We were told that in 1872 Liege produced from about one hundred iron-works some 200,000 tons of pig-iron, 100,000 tons of finished iron, and that Chaleroi produced 400,000 tons of pig and 250,000 tons of worked iron. In this small country, which has an area of but eleven thousand square miles, and a population of less than six millions, there are nearly two hundred coal-mines, and the province of Hainaut alone produces over 2,000,000 tons of coal per year. Valuable zinc-mines exist between Liege and Aix-la-Chapelle, and all of the valuable building-stones are found in large quantities and of fine quality.

Flanders produces nearly $10,000,000 worth of flax per annum, and of an exceptionally fine quality. Verviers employs four thousand men in cloth-manufacture, and the cotton-manufactures of Belgium now employ a capital of £3,000,000 sterling.

371. The condition of the working-people of Belgium is not such as to make them well satisfied. They receive low wages, but the cost of living is also very low, and the difference to be observed between them and between all working-people in Europe and those of the United States is not due to small wages. The money-value of labor and of the necessaries and luxuries of life are fixed there, as in all parts of the world, by the uncontrolled laws of supply and demand. The people lack that enterprising spirit and active disposition which is so universally characteristic, not only of the American native-born citizen, but of the European imported into the United States. That wonderful abundance of all those smaller articles of comfort and luxury which is seen in the United States is entirely wanting there.

In some cases employers are taking upon themselves, to a certain extent, the care of their employés, and are endeavoring to make their condition more tolerable.

As was remarked by the writer immediately after visiting the district* in which the Messrs. D'Audrimont are engaged in such an enterprise, the employer never fails ultimately to receive a bountiful return for all capital expended in providing for the physical, the intellectual, or the moral welfare of his employés. Physical benefits conferred bring back a return in healthful energy; intellectual training gives intelligence which invariably finds application; moral advancement results in an increased sense of duty and of responsibility; and all together promote wonderfully that appreciation of the mutual obligations binding master and man which is the best of all preventives of strikes and of lock-outs and of all those unfortunate disagreements which divert the trades-unions from their legitimate work, of stimulating industry and preserving uninterrupted the prosperity of the working-man, and which bring embarrassment and distress upon all classes. The Messrs. D'Audrimont evidently understand this, and have erected at their collieries at Micheraux, the Hotel Louise, a house of entertainment for their work-people. This house contains 200 beds. The rooms are fitted up plainly, but neatly, with all modern conveniences, and the prices charged for lodging and subsistence are as slight an advance upon cost as will secure the proprietors against absolute loss. Each man pays about a franc and a half (30 cents) per day for lodging, meals, washing, and necessary attendance. A miner, returning from work, goes to the lavatory, removes his begrimed suit of clothes, sends them down by a "dumb-waiter" to the laundry, takes his bath, receives a clean suit of his own clothes in return for those sent down, and makes his appearance ready for his meals, or for cleanly occupation during his "off watch," dressed very like a gentleman, and, with his neat suit and freshly-blacked boots, he experiences a feeling of self-respect rarely known under the ordinary *régime* of less well-administered coal-mines.

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* See Scientific American, 1873; correspondence.

Here the maximum earnings of a miner are stated to be about 90 francs ($18) a month, one-half of which might be saved by a frugal single man.

In the cotton and woolen mills, as well as in many other branches of industry in Belgium, the work-people labor, generally, seventy-two hours per week, and no abatement of time is made for women or for children, in which classes 35 per cent. and 25 per cent., respectively, of the working-population is included. In some cases the working-hours have been reduced to ten, and that without decrease of production. The amount of work done by each hand probably averages less than with us, although the speeds of machinery are about up to our standard. Thus, cotton-looms run 125 to 180 picks per minute; woolen, 140 or 150, and sometimes at higher speed. Cotton-spindles are driven up to 6,000 revolutions on American, and to 5,000 on East Indian cotton. Wool spindles make 5,000 or 5,500, and flax-spindles 3,500 turns per minute. The number of operatives varies from seven to ten per thousand spindles, a number exceeding the figures of our own or English mills. Some of these mills contain 200,000 spindles; and the tendency is, as with us continually toward increasing the size of mills, and securing that increase of economy which is a usual consequence of enlarged production. That sound business policy which dictates the purchase of the best possible machinery is also well understood there, and the less-frequently acknowledged principle that prosperity always ultimately follows honest work and liberal dealing is, perhaps, more generally recognized than among many other manufacturing peoples.

372. France and Belgium are vastly more in sympathy with each other than is either with their common neighbor, Germany. The people of the north of France and the Belgians and the Dutch are much alike in their quiet, steady business ways, and of industrious habits. The former have always been celebrated for manufactures of the finer classes of textile fabrics, and for excellence in all the arts which demand exceptionally good taste and an appreciation of the beautiful.

The great silk-industry of France has been growing from the time of Francis I, and now consumes over 5,000,000 pounds of raw silk in addition to that raised in the country. About 50,000 tons of beet-root sugar are made annually; nearly 150,000,000 pounds of cotton are consumed, and in coal and iron the production and consumption are only second to Great Britain.

For many years the silk-manufacture, having its center at Lyons, and employing a large proportion of the population of St. Etienne, Tours, Avignon, and of many people in Paris. The cotton goods made at Rouen, Troyes, Lille, and the broadcloths of Abbeville, Louviers, Sedan, Amiens, and Rheims; the carpets of Aubusson and Paris; the laces and linens of Valenciennes; porcelain of Sevres and Limoges; the clock and watch making of Paris, and the great variety of fine jewelry and "fancy goods" made in the same city, have been among those acknowledged as the best in the markets of both continents.

The total number of spindles in France is stated at two and a half million in silk-mills and nearly five million in cotton-mills.

In 1872 France, with 228 blast-furnaces, produced more than a million tons of cast-iron, principally coke-iron; the amount of charcoal-iron was about 180,000 tons. A hundred and forty thousand tons of steel were made, one-third of which was made at Le Creusot.

Paris is not usually regarded as a manufacturing city, but it is the seat of a vast number of minor industries, and contains some establishments of large size, and interesting to the engineer as well as to the ordinary traveler. Several of the great technical schools of France are at Paris, and some of the auxiliary establishments of the French army and the headquarters of the several departments of government are in the city.

While in Paris we visited, among other places of interest, the Conservatoire des Arts et Métiers, the famous École Polytechnique, the École des Mines, and the École des Ponts et Chaussées.

373. The Conservatoiré des Arts et Métiérs is, to the engineer, one of the most interesting institutions of Paris. We were kindly entertained by the director, General Morin, and by the sub-director, M. Tresca, and were afforded an opportunity to examine the wonderful collection which has been gathered here from all directions, and which represents every department of industry.

The most interesting among the many specimens of early engineering was the steam-carriage of Cugnot, built in 1770, and which was probably the first locomotive-engine ever constructed. It was quite a large machine, probably weighing a ton or more. The boiler was carried behind the carriage and supplied steam to a pair of singularly-constructed engines, which turned one pair of wheels.

These engines were single-acting, and worked a ratchet which engaged with the teeth cut on the disks secured to the wheels. It was remarkably well made for so ancient a piece of work.

The original looms of Vaucanson and Jacquard are preserved here in the Salle des Filatures, and in other departments are almost equally interesting relics. The collections are well arranged and classified.

M. Tresca had a mechanical laboratory, in which are many of the larger objects belonging in the collections, but it is principally occupied with apparatus for testing the efficiency of machinery and with illustrative models driven by power.

Nothing like this collection exists in the world. In its extent and completeness it is unexampled.

374. The growth of this great school has been a gradual one, although liberally aided by a government which, although never itself stable, has been noted, through all its mutations, for the substantial aid which it has liberally accorded to its educational institutions.

Descartes, the distinguished philosopher, is claimed to have been the earliest to propose public instruction for working-people.* He proposed to built a large lecture-hall for each trade, annexing to each a cabinet containing the apparatus appropriate to that department, and to place each of these lecture-rooms in charge of a professor familiar with the subject there to be taught, who should present to the students the principles of his art in proper form, and who should be capable of answering the questions addressed him by his pupils in relation to all details of practice.

It was a century later, however, that this project of Descartes took shape, and the actual commencement of the work is attributed to the great mechanic, Vaucanson.

This distinguished man, previous to 1775, had gathered together, at *l'Hotel de Mortagne*, the first collection of machinery and apparatus which was ever devoted to public use in the manner proposed by Descartes. At his death, Vaucanson bequeathed this collection to the state, and it thus became the germ of this splendid institution which is now so famous.

M. de Vandermonde, the first director, added five hundred machines to the collection between 1785 and 1792.

In 1793 a "*commission temporaire des arts*" was formed, by decree of the *Convention Nationale*, consisting of MM. Vandermonde, J. P. Leroy, Conté, Beuvelot, Molard, l'Abbe Gregoire, and the celebrated physician, Charlés. This commission did a noble work in collecting valuable apparatus and models, and in preserving them from injury during the riots and the turmoil of that sad period in French history.

By a decree of the convention, it was soon after ordered that a "*conservatoire des arts et métiers, un dépôt public de machines modeles, outils, dessins,*" &c., should be established, and that three "*demonstrateurs*" and a designer should be employed. After some delays, the new institution was established in the old priory of *Saint-Martin-des-Champs.*

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* The Marquis of Worcester, the distinguished inventor of one of the earlier forms of steam-engine, two hundred years ago, earnestly urged the establishment of a definitely-arranged system of technical education, which should combine instruction in science and in its useful application in the arts.

The school has experienced the vicissitudes always to be anticipated in such cases; but its collections have never ceased growing, and its field has been extended by the addition of new departments and the establishment of new professorships, until it now has a faculty of fifteen members.

Many of the most noted French savants have been members of its councils or of its faculty. Thenard, Charles, Darcet, Dupin, Say, Clement, Berthollet, Chaptal, Gay-Lussac, Arago, Pouillet, Poncelet, Morin, Tresca, Ollivier, Bequerel, Payen, Peligot, Moll, Alcan, and others have all been, or are at present, in the lists.

The names of General Morin, the *directeur*, and of M. Tresca, the *sous-directeur*, are well known to every educated engineer and mechanic, and their works have assumed a permanent place among "engineering classics."

375. The works of Arbey, the builder of some of the excellent machinery noticed at Vienna, are at Paris; the great establishment of Cail & Cie. are also here. The arrangement of the former (Fig. 217) is somewhat like that noticed at several other establishments. The heavier tools are on the lower floor, and lighter tools are mounted in galleries on either side. Before visiting the latter, we made a journey to Le Creusot to visit the great establishment of Messrs. Schneider & Co., which produces a large fraction of all the iron and steel made in France.

376. CREUSOT.—This immense establishment has grown up from a very insignificant beginning during the past century. The first buildings were erected in 1782, and the mining of coal from the beds which underlay the present city and works, then called Charbonnières, has never since been intermitted. The elder M. Schneider, who still lived* at the time of our visit, an active, intelligent old gentleman, purchased the place

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*EUGENE SCHNEIDER.—We regret that we are compelled to record the death of another of those distinguished engineers to whom the world is so much indebted for its material prosperity. In Great Britain, the Dowlais Works, in Prussia, the great establishment of Krupp, at Essen, and in France, the immense works of the Messrs. Schneider are illustrations of the success which may sometimes attend earnest application and the exercise of a talent in organization and in direction such as is essential to the prosperity of any large manufacturing community. In all these cases, the marvelous accumulation of capital and the creation of a great city by the industry of a single proprietor, and during a single life-time, has been the most remarkable fact.

Eugene Schneider and his brother Adolphe purchased the works at Le Creusot in 1836. The works had been established a half-century earlier by a company in which Louis XVI held an interest. It had never prospered, however, and the Messrs. Schneider bought it for about two and a half millions of francs, after thirty millions had been expended upon it. In 1838, the first locomotive was built here for a French railroad, and Le Creusot has supplied nearly all that have been made for them up to the present time. There were then employed at Le Creusot about 2,000 men. In 1842, M. Bourdon, the celebrated engineer and inventor, then in the employ of the Messrs. Schneider, invented and built for the works a steam-hammer, at about the same time that Nasmyth introduced his in Great Britain. In 1845, M. Adolphe Schneider was killed by a fall from his horse, and Eugene succeeded him in the Chamber of Deputies,

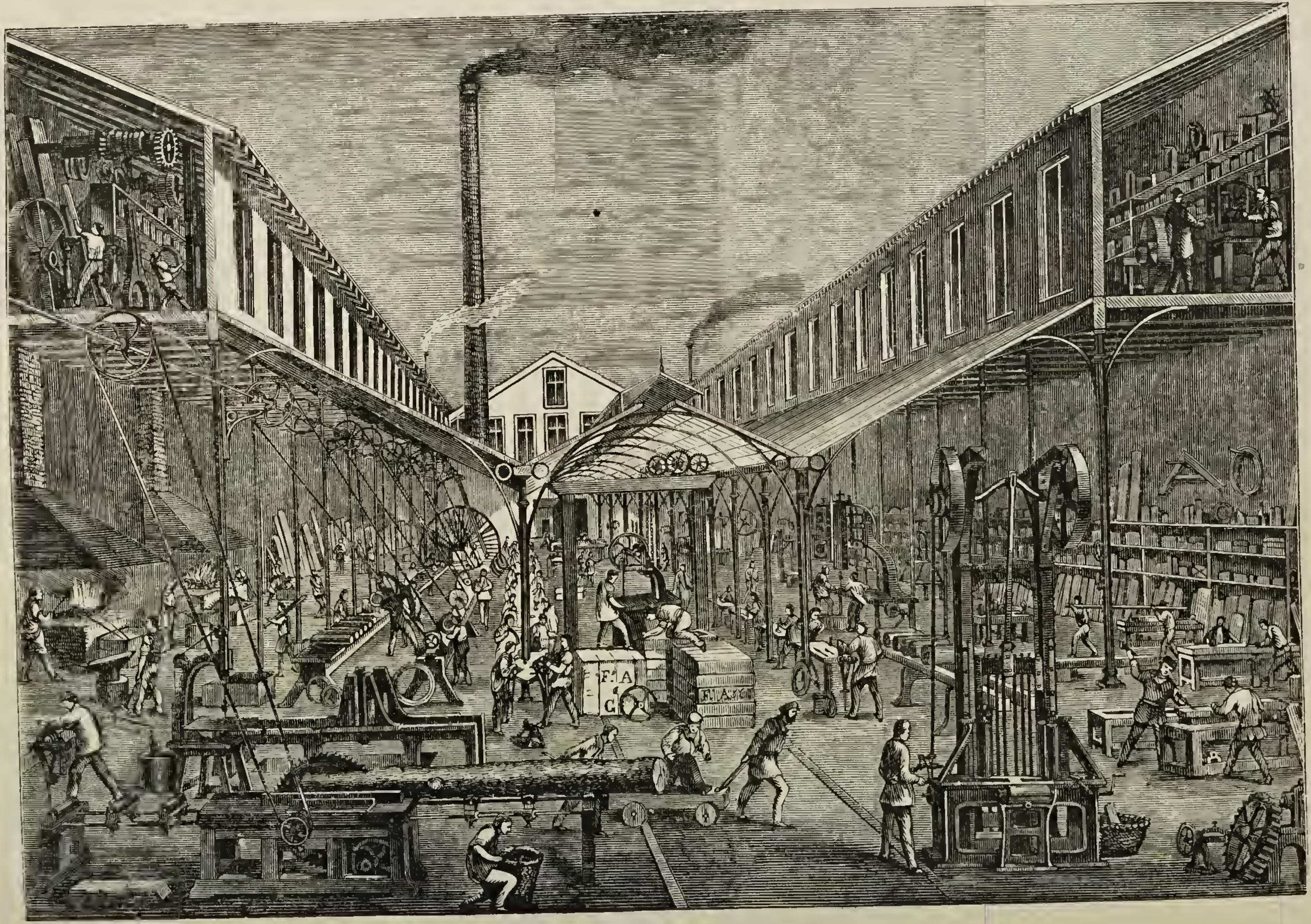

FIG. 217.—Works of Arbey & Co., Paris.

in 1837 for about a half million dollars, at which time its production was 40,000 tons of coal and 6,000 tons of iron per year, and the number of workmen employed was less than fifteen hundred. The town had a population of about three thousand.

377. The wonderful change which has occurred during this century of development was best realized by the visitor when he obtained a view of the great collection of mills as he approached them in train from the Paris and Lyons railroad. The description given by the writer at the time would not be out of place here.

Leaving Paris early in the morning, we reached Le Creusot late in the evening. Long before reaching the latter city we could see across the country great masses of smoke rising slowly from the valley and floating across the hills like heavy thunder-clouds, obscuring large tracts of the country, which was elsewhere beautifully illuminated by the bright light of the moon, then just past the full. As we finally skirted the town, nearing the station, a sight burst into view such as is seldom witnessed, and to which no verbal description can do justice. The vast clouds of smoke which we had been watching from miles away were issuing from the tops of hundreds of chimneys and from the midst of numbers of great blast furnaces, which rose far above the surrounding buildings. The long structures covering the rolling-mills and forges were plainly seen through the gloom, lighted up by a ruddy glow from great masses of hot metal passing through the rolls, or by the brighter glare of scores of forge-fires; and on the hill above and behind the works, barely revealed by the light of the partly-obscured moon, we could see the populous town which has grown up here, founded and supported by this marvelous example of recent industrial progress. A dull unintermitted roar of escaping steam, the loud clatter of gearing from the rolling-mills, and the rumble of the rolls, with the unceasing concussions of many steam-hammers, the sound of loud voices, now and then rising

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and was again elected in 1846. Meantime, the works were carried on under the direction of his son, who, by his death, is left to assume nominally that entire responsibility which he has actually borne, although still a young man, for many years. Eugene Schneider was made minister of agriculture and commerce in 1851, and was at the same time decorated with the insignia of a commander in the Legion of Honor. A little later we find him a member and vice-president of the Corps Législatif, remaining by re-election in 1857 and 1863, and becoming its president in 1865.

During all this period his establishment at Le Creusot was rapidly increasing in magnitude and importance, and our readers will remember the description given of it by our correspondent, Professor Thurston, after his visit to M. Schneider in 1873, on his return from Vienna. The venerable founder was then at home, and was still exhibiting an earnest and intelligent interest in its affairs, although he had then surrendered all administrative control to his son.

M. Schneider has, throughout his life, taken an active part in all the public affairs of France which are concerned in her industrial progress. He was a member of the general council on manufactures, a member of the board of regents of the Bank of France, and was president of one or two societies formed for the encouragement of industry. He was decorated with the Grand Cross of the Legion of Honor in 1868.

At the time of his death the enlargement of the Creusot establishment, which had been commenced at the time of the visit of our correspondent, had been largely comabove the noise of machinery, and the barking of the numerous dogs in the city beyond, mingled and produced almost as novel and exciting an impression upon the ear as did the strange and interesting scene upon the eye.

The works now furnish employment to nearly sixteen thousand people, of whom probably ten thousand work in the mines.

Twelve large blast-furnaces were in blast, which produce annually over a hundred thousand tons of iron, which is consumed in the Bessemer works and the iron-mills. Fifty thousand tons of steel and twenty thousand tons of iron rails are made, and the machine-shops turn out a hundred locomotives and an immense amount of other machinery.

The blast-furnaces recently built are twenty meters in height, and others, of earlier construction, are twenty-five meters high. They are supplied with blast heated to one thousand degrees in Whitwell and Cowper stoves, both of which are used.

Ores and fuel are obtained on the place, and are of good quality. For Bessemer metal, imported magnetite ores from Algeria are used, which are said to be as pure and rich as any in the world. The metal for the converters is brought directly from the blast-furnaces in large ladles, into which it is tapped from the furnace, and which are drawn on a line of rails to the converters by horses. This peculiarity of Creusot practice is probably one of the important elements of successful competition with other works.

It was at this place that the Siemens-Martin process was first made successful. It is still used in the production of the softest grades of steel. Both at the works and at Vienna, remarkably beautiful samples

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pleted. The works are of such extent as to cover over 800 acres of ground, employing about 15,000 workmen, raising over 700,000 tons of coal from the underlying coal-beds, making nearly 200,000 tons of pig-iron, 100,000 tons of puddled iron, and 75,000 tons of steel per annum. They turn out 100 locomotives per year, immense quantities of machinery, bridge-work, steam-engines, and other manufactures in metal.

The coal-mines employ 1,200 men; there are thirteen blast-furnaces, three sets of Bessemer converters, six Siemens-Martin furnaces (which were first introduced here) rolling-mills and forges employing over 3,000 men, containing fifteen steam-engines and covering thirty acres of ground. The engine-shops are at Chalons-sur-Saone, and furnish employment to 2,500 men. At Le Petit Chalons, iron-ship-building is carried on and bridge-construction is a principal branch of industry. The whole establishment now has in use over 3,000 steam-engines, having an aggregate power of about 20,000 horses.

The town of Creusot has grown from a little village, as found by the Messrs. Schneider, containing, possibly, 3,500 people, to a city of 25,000 inhabitants. It is dependent entirely upon the works for its maintenance. The director, M. Henri Schneider, is also the mayor of the town; and this patriarchal form of government is not the least interesting feature of the place.

M. Schneider will not soon be forgotten. His skill as a mechanical engineer, his administrative ability, his splendid power of organization, his statesmanship, his patriotism, and, above all, those noble traits of character which endeared him to all with whom he became associated, have given him the fame which is accorded to the successful in every branch of life, and have secured for him that grateful remembrance which is the greater reward of a life full of good works. It is pleasant to be able to feel that his mantle has fallen upon one who is well worthy to wear it.—*Scientific American, Supplement.*

of this steel were shown. The great advantage possessed by this process in the production of low grades and fine qualities of steel arises from the fact that, when the steel is ready to be tapped off, it may be tested to determine its precise adaptation to the proposed use; if not of the required degree of carbonization it may be retained on the hearth under a reducing, or an oxidizing, or a neutral flame, as desired, and pig-metal, spiegel, or wrought iron, which may be needed, can be added, if necessary. The molten metal may be held in the furnace as long as may be wished, and finally, when precisely of the quality demanded, may be tapped off with a certainty that it is of the right composition.

Some of these steels contain as little as one-fourth of one per cent. carbon, and are wonderfully ductile. Nothing resembling some of the samples shown there had been met with by the writer. Since his return, a few specimens have been sent for test to the Mechanical Laboratory of the Stevens Institute of Technology, which are of similarly low grade in carbon and equally remarkable for ductility and resilience. The Midvale Steel-Works of Philadelphia furnished these specimens.

The Siemens regenerative furnace is in use at Le Creusot, and eight new furnaces were in course of construction at the mills. The rolling-mills were well built and well arranged for doing work efficiently and promptly. The buildings are very excellent in design, substantial in construction, and well adapted to such purposes. The rolls were strongly made and were driven at good speed, and the iron was well handled.

The machine-shops were of less interest. The forge contained some hammers of large size; the heaviest had a weight of 15 tons.

We admired particularly the arrangement of the drawing-rooms and offices. They were unusually well placed, neatly built, and well furnished, and were light, airy, and very pleasant. The office of the superintendent of each department was placed in telegraphic communication with his section of the works, and he gave orders to his subordinates and received their reports without leaving his chair. All offices were within convenient distance of the rooms of the proprietor. The organization and administration were simply admirable. The *personnel* of the establishment comprised a larger proportion of well-informed and well-educated officials than we had met in any similar establishment in Europe. The workmen seemed, as a class, very intelligent and industrious.

378. A visit to Lyons, the center of the silk-manufacturing industry of France, enabled us to see something of the manufacturing of South France. The manufacture of silk has constituted the principal industry of this district for many years. It was first commenced about three hundred and fifty years ago. Twenty-five years ago it employed over fifty thousand looms, consuming a million of pounds of the raw material, valued at $30,000,000, and producing goods worth nearly double that amount. The business now employs about seventy thousand looms and double that number of workmen, and the value of the product is estimated at $80,000,000. The work is not done in large manufactories,

but in the houses of the people or of the master-workmen. A very large quantity of the Lyonnese silk is sent to the United States.

The attempt was made some years ago to found a "Permanent Industrial Exhibition" at Lyons. We found the buildings, which covered a great area of ground, nearly empty; the enterprise was evidently a failure. We found a few exhibits still remaining. A horizontal stationary engine, by Duvergier, of Lyons, was, in some respects, worthy of study. Its regulator adjusted a single-ended link, and the main and cut-off valves were moved by the same eccentric. The link could be adjusted by hand when desired. The cylinder was overhung from the end of the frame, like the arrangement adopted sometimes by Corliss.

MM. Marvel Frères exhibited a chain-cable weighing 82 kilograms per link. The same firm exhibited an armor-plate, measuring 6.26 × 1.485 × 0.270 meters, and weighing 19,750 kilograms; a bridge-plate, 22.5 × 0.5 × 0.12 meters, and weighing 1,053 kilograms; several heavy crank-shafts, and an armor-plate 6 inches thick, doubled up, as was stated, *cold.*

The Société Anonyme, of Charente, had on exhibition some very fine castings of Siemens-Martin steel; they were remarkably good. MM. Chevalier & Grenier, of Lyons, presented a horizontal compound engine, with a boiler fitted with superheater, and with removable tubes and fire-box, like that exhibited at Vienna. The governor was of the parabolic class, with ball-guide, and attached to the throttle-valve. The main steam-valves are plain and can only cut-off by the lap of the valve.

379. Cail & Cie., at Paris, have a large establishment on the Quai de Grenelle, beyond the Champs de Mars, in which they employ nearly four thousand men. These works produce large numbers of locomotives, steam-engines, and machinery, and an immense quantity of sugar machinery. The buildings are low, usually of but one story, are well lighted and are crowded with machinery. Iron columns and girders support the roofs. They are not as conveniently arranged as those of some other establishments visited, but a railroad-track is carried through every building, and a number of small switching-engines are kept employed in the transportation of material from one to another.

The tools in use are not comparable in efficiency to those familiar to manufacturers in the United States. Some recent improvements and some modern tools are distributed throughout the works. The character of the work done was very good in all departments. We noticed that all scrap was kept apart and carefully assorted.

The locomotive-shops were said to turn out a hundred and twenty engines per year. The number of draughtsmen employed was given as *one hundred and ten;* either the number is incorrect or an immensely greater expense must be incurred in getting up new designs than is usual in such establishments, and must prove a heavy tax. The variety of work done here is greater than is usual in such places, and that fact may possibly account for such extraordinary development of this department.

CHAPTER V.

MANUFACTURING ESTABLISHMENTS OF GREAT BRITAIN.

No important advance since 1871; Sharpe, Stewart & Co.'s locomotive and tool works; Crewe, and the works of the London and Northwestern Railroad Company; British iron-making; The Cumberland hematite district; Barrow, and its steel-works; Cumberland ores; Barrow steel; Tests made by Fairbairn, and at the Stevens Institute of Technology by the author; The Cleveland iron-district; Dimensions of furnaces; Ores; Fuel; Flux; Engines; Source of economy in working; Lancashire: James Watt & Co.'s works at Soho; Low Moor iron-works; Scotch iron-making practice; Glasgow and its industries; Iron ship-building; Iron vs. wood; Elder & Co.'s Fairfield works; R. Napier & Sons; Other British firms; Efficiency of steamers; Dimensions and performance of steam-vessels; The British navy; Her Britannic Majesty's iron-clad Monarch; Classification of war-vessels; Hull of the Monarch; Turrets and armament; Engines and boilers; Performance; British naval policy; The Devastation; The Inflexible; Sir Joseph Whitworth & Co.'s machinery and gauges; Whitworth ordnance; Comparison with the Woolwich system; Whitworth's compressed cast steel; Value of new and resilient metals; Sheffield; Steel and armor plate; Thomas Firth & Sons; Sir John Brown & Co.; Cammell & Co.; South Wales; The Dowlas's works; The Siemens steel processes; J. Penn & Sons' trunk and oscillating engines; Shipbuilding on the Thames.

380. After leaving France we still had a short time to give, before the sailing of the steamer in which we had taken passage, to the exploration of some of those British manufacturing districts of which we had seen products at Vienna. At a visit made two years previously to the principal of these districts, partly on business and partly for the purpose of obtaining general professional information, the writer went over very nearly the same ground. There seems to have been but little change, either in general standard practice or in matters of detail during this interval.

A brief description of a few of these leading establishments in each of the principal of these districts will be quite sufficient to indicate the points of resemblance and of difference between them and similar establishments in the United States.

381. **Sharpe, Stewart & Co.**—Sharpe, Stewart & Co., of Manchester, are among the best-known and deservedly-distinguished of British locomotive and machine building firms. Their practice is probably as fairly representative of the best English methods as that of any other shop in the country. The firm has been long known, and, like those of nearly all old establishments, its works have grown into their present shape very gradually, and the buildings are neither well arranged nor

well adapted to modern methods of work. Both buildings and tools are too generally old and dilapidated, and are such as would not be retained in use by an American firm of equal wealth and standing. It is the fact, however, that in no part of Europe is the economy to be obtained by the substitution of modern automatic and rapidly-working tools for half worn-out machines of older design so well appreciated as in the United States, and a "rotation in tools," as some engineer expresses it, is not generally understood to be an essential to the greatest success in manufacturing.

Some of the older tools were here fitted with recent improvements in details, as, for example, the Whitworth tool-holder, which reverses the edge of the tool of the planing-machine at each movement of the table and places it in position to cut each way. The tool is carried in a cylindrical holder, with vertical axis, and with its edge in the axial line. Simultaneously with the reversal of motion of the table this tool-holder makes a half revolution and presents the cutting-edge of the tool in position for taking a cut in the new direction of travel. The tool is usually round-nosed, to avoid the difficulty which would be met with in securing the precise adjustment of the common side-tool. A slotter, fitted with two tools and used in dressing the cranks of locomotive-axles, was another illustration of a successful attempt to economize labor. All machine-tools were fitted with automatic feed-motions.

The firm are building large numbers of locomotives. Their practice is in some respects in advance of that of the majority of British builders, and some of their designs are very similar to those which have long been standard in the United States. In some points it resembles that subsequently seen at Crewe, in the shops of the London and Northwestern Railroad Company. The variety of styles of engine, both passenger and freight, was remarkably great, and special designs seemed to have been frequently made for foreign markets, to which a large number of engines have been supplied by the company. The use of outside cylinders is more usually adopted here than in the general practice of British firms. The simplicity of parts and the superior strength of the straight axle in this plan of engine have long ago made it the standard design in the United States. It is much less frequently seen in Great Britain, and the breakage of cranked axles is therefore not infrequent. The driving-wheels are all flanged, and even the intermediate wheels are not left, as in American engines, without flanges. The tires are made of Vicker's crucible-steel. The engine-frames are made of plate, and are *planed* on each side to bring them to size. This seems an operation for which some less expensive substitute should be found. The plan of grinding practiced at Crewe is probably far preferable. The fire-boxes of the boilers of the locomotives are made usually of copper. The tube-sheets are made an inch or more in thickness where they receive the tubes, and are worked down to the same thickness as the remaining part of the fire-box where clear of the tubes. This plan was entirely unfamiliar to the writer, and is probably but little practiced, if known at all, in the United States. Where it can be done conveniently, the riveting is done by steam with a rather light steam-riveter, which sets up seven-eighths rivets with two blows. The edges of the sheets are planed instead of being left to be chipped after riveting up, with the serious risk of injuring the lower plate along the edge of the lap. The practice of planing the edges has been introduced into the United States, but is far less general than it should be. The shells of the boilers were made of $\frac{3}{8}$ to $\frac{1}{2}$ inch plate, butt-jointed, with the covering-strips on the outside except where the laps occurred. The work was all carefully laid out and well done. The seams looked well along the laps and at the corners, and the rivets were of good quality and well headed. The machine-work was all good, and some of it was exceptionally excellent. The firm make a great variety of small machinery and of attachments to engines and boilers. The effort seems to be made to make them cheaply and to give them efficiency without expending anything for finish. They are the licensees, in Great Britain, of the patents of Giffard on his injectors, and of the Messrs. Sellers for some of their finest tools. The firm have made, it is stated, over 25,000 Giffard injectors in one year. We found nothing to demand notice in the foundery. Scotch pig seemed to be largely used; we saw a considerable amount of Glengarnock and Gartsherrie in the stock-piles.

382. CREWE.—LONDON AND NORTHWESTERN RAILROAD REPAIR-SHOPS.—The works of the London and Northwestern Railroad, at Crewe, nearly midway between London and Liverpool, are exceedingly interesting to the engineer. These works employ about 6,000 men, and the city which has been built up around them contains nearly 25,000 people, who are all directly or indirectly dependent upon them for support. In this establishment a hundred and fifty locomotives are constructed each year, and all the locomotive-stock of the company, 1,700 or 1,800 in number, are kept in repair. The low steel, and much of the iron and other material used in the shops, are made on the grounds; even the bricks which are to be used in new buildings are made here, a large annular, perpetual kiln, of the Hoffman kind, furnishing them in sufficient numbers and at comparatively low cost. They are molded in a powerful machine, built at Rugby, which is capable of turning out 30,000 per day.

The works grew into their present shape under the superintendence of Mr. Ramsbottom, who had recently left Crewe, and had been succeeded by another distinguished engineer, to whom the writer is indebted for essential favors. Mr. Ramsbottom planned the works, and has made the establishment one of the finest of its kind in Europe. He is one of the most ingenious and boldest engineers living, and has introduced here some of the most radical departures from standard designs and practice and some of the most effective and original machinery to be seen in Great Britain.

The steel-works contain four 10-ton converters, which are kept quite well employed; their product is converted into boiler-plate, rails, tires, and running-parts of engines. The accessory apparatus is well designed and well arranged. Our distinguished American designer, A. L. Holley, could not have done much better had he planned these steel-works.

The foundery is large, well built, finely lighted, and is furnished with a number of hydraulic cranes near the ends, and has a strong, quick-working, travelling crane, running from end to end. It is well fitted up for making large numbers of small castings, and the work seen finished and in progress was excellent.

The rolling-mill contains large plate-rolls driven by the Ramsbottom reversing-engine, of which the use is becoming quite common in Great Britain. This engine is attached directly to the train, and makes the same number of revolutions as the rolls. Instead of reversing the mill at each pass by cross-gearing and clutches, as is usual in old mills, the engine is here reversed by means of the Stephenson link commonly employed on marine engines. In order that reversing may be done promptly and with certainty, the engine has been made without a fly-wheel, and is given great strength. It has two steam-cylinders coupled to cranks, set at right angles with each other, and the valves are given very little of either lap or lead. This engine has not been introduced to any extent in the United States. The system of three-high rolls, with the rising and falling table introduced by Mr. Charles Hewitt, for iron, and afterward by Mr. Holley and Mr. Fritz in steel, mills, is usually thought quite as good, and by many engineers preferable.

The steel-works and the puddling-mill, which latter contains about a dozen furnaces, keep the rolls well employed.

The peculiar steam-hammer in use here is one of the striking innovations on ordinary practice with which Mr. Ramsbottom is to be accredited. It consists of two immense masses of iron forming the hammers, which are mounted on carriages sustained by small, strong, friction-wheels, and move toward or separate from each other by moving horizontally on rails. Between them is the anvil, which merely takes the weight of the piece to be worked, while it is struck simultaneously by the two hammers which approach it from either side. The hammers are driven by large steam-pistons, which are, in this case, set below the floor and under the anvil. This hammer requires no such foundation as is needed by the usual form of steam-hammer, and it possesses the apparently generally unrecognized, but nevertheless important, advantage, that none of the energy of the blow is wasted and misapplied to the shaking of the earth and the injury of the buildings; it is all usefully applied to the shaping of the work. For many kinds of work this hammer has such decided advantages over the standard forms that it seems surprising that it has not become more widely known and more generally introduced. There were three of these hammers in use at Crewe. One of the smaller ones was used in working out the cone-shaped steel castings which were made for tires. In making these tires, the castings were taken for finishing to a singularly-constructed stretching-mill, in which they were forced, by a process of rolling and pulling, along an iron cone, by which they were, at a single operation, given the required size. The plan was exceedingly ingenious, and cannot be described without complete drawings. With good tough metal it works well. Engine-tires were all carefully turned, but the tires used for tenders were left as they came from the mill.

The puddling-furnaces at Crewe were of the ordinary form. The heating-furnaces were those of Siemens, and the amount of work done at these works may be well indicated by the fact that these furnaces consume 200 tons of fuel per day in the gas-producers.

The boiler-shop was as well planned and built as the foundery. Here they were using steel in the shells of their locomotive-boilers, and were trying it in fire-boxes where they had previously used copper exclusively; the results were reported to be satisfactory. The use of steel in locomotive-boilers has, so far as the writer has had knowledge, always been satisfactory in result where the metal has been obtained of uniform quality. If given just sufficient carbon to enable it to be melted in the crucible or on the hearth, and to be made so fluid as to become thoroughly homogeneous, steel is always found best; if it contain much above one-quarter of one per cent. carbon, it is likely to prove unsatisfactory, sometimes hardening, and frequently cracking, if used in fire-box plates.

In riveting, the work is done, where possible, by the steam-riveter, and usually the rivet is closed up by two blows. The older riveting-machines were too light to do good work at a single blow; and it may be doubted whether it is not better practice to use a light machine in the manner described than a heavy machine, striking a single blow, unless, like the machine of the Providence Steam-Engine Company, one die is used to hold the sheets together, while the rivet is headed up by a second die driven by an independent steam-piston. The seatings for man-hole plates, safety-valves, dome-tops, and such details, are of wrought iron, struck up in a single piece—an excellent practice, and one which should be adopted universally. The usual habit in the United States of using castings for such parts is vastly less satisfactory and is anything but creditable.

The machine-shops were extensive, well lighted, and well arranged, and contained some excellent tools; the latter were principally of Whitworths manufacture.

Some peculiarities of practice in making details were observed here. Eccentric straps were usually bushed with a kind of Babbitt or white metal; connecting-rods were made solid at the ends, instead of being fitted with costly straps, with their gibs, keys, and set screws, and were simply bored out to receive bushings of white metal in place of the usual form of brass box. These bearings run well for a year or more; when they begin to shake, they are taken out, recast, and replaced, an operation of little cost and requiring very little time. This method was reported to have proved perfectly satisfactory. Its cheapness and convenience are important recommendations.

The boiler-shells are usually 48 inches diameter and of ⅜-inch plate, and are subjected to working-pressures of 120 or 130 pounds per square inch.

Both feed-pumps and injectors are used. The latter are of a simple, cheap, and quite effective form. which resembles slightly some of the cheap styles used in the United States and elsewhere.

Here, as all over Europe, the frames of the locomotives are made of heavy iron plate 1⅛ inches thick, cut into shape and tool-dressed to fit; this is done by piling six or more upon the planer-table and working all together. When given the desired outline they are removed from the cutting-tools and placed in a tank, where they are flooded with water and are ground smooth by a horizontal grindstone; the method seems to satisfy the manager, and was said to be both effective and inexpensive.

The style of locomotive now usually built resembles the American type somewhat, but has driving-wheels of larger size. On passenger-engines these wheels are from 6½ to 8½ feet in diameter; the former size is the most common. Formerly, very large wheels were used on fast engines; they were not infrequently 8 and were sometimes 10 feet in diameter; the Cornwall, with drivers of the latter size, was, at the time of this visit, at work on the line. These large wheels are only in single pairs; they are said to shake too seriously at high speed; they are driven by outside cylinders. The smaller sizes are usually built for engines having inside cylinders and two pairs of coupled drivers; they are now used in nearly all new passenger-engines, as on railroads in the United States. Freight-engines, or "goods-engines," as they are called in Great Britain, are given smaller wheels.

In these engines the solid-bar link is adopted; it possesses some important advantages over the strap link; it is simple and strong and wears well.

Trucks, or "bogies," are not used by British engineers, who consider that the short wheel-base introduces a serious element of danger in its liability to swing across the track, and who think that the small leading-wheels, necessarily used under a locomotive truck, are also objectionable. They prefer a single pair of larger leading-wheels carried in a rigid frame without radius-bar.

The Ramsbottom packing-rings are used on pistons. These are single small rings sprung into grooves turned in the face of the piston. This dispenses with followers or "junk-rings," and is inexpensive. The same plan has been frequently tried in the United States with many variations of proportions and with varying success.

The wrought-iron wheel is almost exclusively used, but cast wheels are on trial. Quite recently the distinguished American engineer Mr.

W. W. Evans, of New York, has exported American wheels to foreign countries. No success has been met with abroad in making these wheels, and it does not seem probable that such wheels as our roads have used so long can be made in other countries, until such metal as we use can be obtained there.

A system of mechanical firing was in use at Crewe under shop-boilers, and was reported to be very successful.

This great manufactory should be visited by every one who desires to see the best of British practice and the most original inventions of this class to be found in the country.

383. BRITISH IRON-MAKING is seen in its most characteristic development in the newer iron-making districts of Cumberland and Cleveland. There has been, during past years, a continuous but not very rapid improvement in the methods and plant, which now seems to have reached its limit. Economy in the production of iron from the ore is promoted by increasing the size of furnace and elevating the temperature of blast. The limit in the first direction is practically determined by the strength of the fuel, in most cases. When the furnace is given a height at which the fuel is crushed under the superincumbent weight, further increase of altitude becomes impossible. As the maximum diameter is determined by the altitude, it also becomes impossible to exceed a certain capacity of furnace, which will vary with every variation in the hardness of the fuel. Where the limit is not thus fixed, it is found that the increase of economy becomes less and less as the magnitude of furnace increases, and it finally becomes so slight as to be balanced by higher proportional increase of direct and incidental expenses of building and working.

In the Cleveland district the strength of the coke used as fuel is such that the latter causes have determined the limit, and the furnace now apparently most generally approved is about 75 or 78 feet in height and 26 or 27 feet in diameter of bosh.

The increased economy which attends elevation of temperature of blast has similarly attained a limit in practice, which is somewhat above the highest temperature yet actually reached. Where iron hot-blast stoves are used, they limit the temperature of blast to about 1,200° as a maximum, as they are liable to crack seriously at a higher range. With the Whitwell, the Cowper, the Sellers, and other stoves in which more refractory materials than iron are used, the temperature has been carried several hundred degrees higher, but with very little if any advantage; on the whole, and practice seems to have settled down at about 1,200° F.

384. CUMBERLAND HEMATITE-DISTRICT.—In the northwest corner of England, near the celebrated "Lake District," and in the neighborhood of the well-known ruins of Furness Abbey, there has lately sprung up an immense business in the mining of ores and in the manufacture of iron and of steel. It is but a few years ago that the now

well-known Cumberland hematite-ore was found to be the only British ore well adapted for the Bessemer and Siemens process of steel-making. The section of country has, in consequence of this discovery, been rapidly settled, and manufactures of metal have been developed here with a rapidity only equaled in the neighboring Cleveland district and in the western portions of the United States.

As the present tendency of improvement in the applications of metal is evidently to the introduction of the low grades of steel and its substitution in nearly all directions for iron, a capacity for the production of steel in large quantities and for long periods at small expense, either in making or in transportation to the market, will probably ultimately determine the position to be held by any country in reference to the markets of the world. The standing of Great Britain, therefore, is not improbably dependent upon the extent of this one deposit of ore and upon the skill and economy with which it is worked. Our own country, with its vast deposits of rich and poor ores, seems far more likely than Great Britain to supply the world, in the near future, with its steel.

385. The works of the several firms producing steel and iron in the Cumberland district are situated in and near the city of Barrow. This city has grown up since the discovery of the value of this ore from a mere village to a town of nearly thirty thousand inhabitants. The whole of this section is owned by the Dukes of Devonshire and of Buccleugh, of whom the one holds the lands and the other all manorial rights. They, with a few other capitalists from other portions of England, have controlled the whole of the immense mining and manufacturing interests now concentrated here.

The first blast-furnace was erected in 1859 by Messrs. Schneider, Hanney & Co. The first steel-making plant was erected by Sir James Ramsden, in 1864. In 1866, these establishments passed into the possession of the Barrow Hematite Iron and Steel Company, which also acquired title to the mining-property, and thus secured control of all the industrial enterprises of the district.

At the time of our visit there were sixteen blast-furnaces at work. They varied in height from 56 to 61 feet, and in diameter from 16 to 19½ feet. The largest yields 400 tons of iron per week, and is thought to be quite as large as is advisable for this district. The temperature of blast was stated to be about 900° F.; an increased temperature had been found to give no advantage. The blast was furnished by nineteen blowing-engines which average about 100 horse-power each. The total production of cast iron was given at about 300,000 tons per year, which was principally of dark foundery-grades, well adapted to use in the Bessemer works. The ores are used without mixture, and seem to work well in the furnace.

The steel-works contain eighteen converters and produce about 100,000 tons of steel-rails, tires, and other material per annum. The whole establishment was unusually well arranged, and the buildings were well

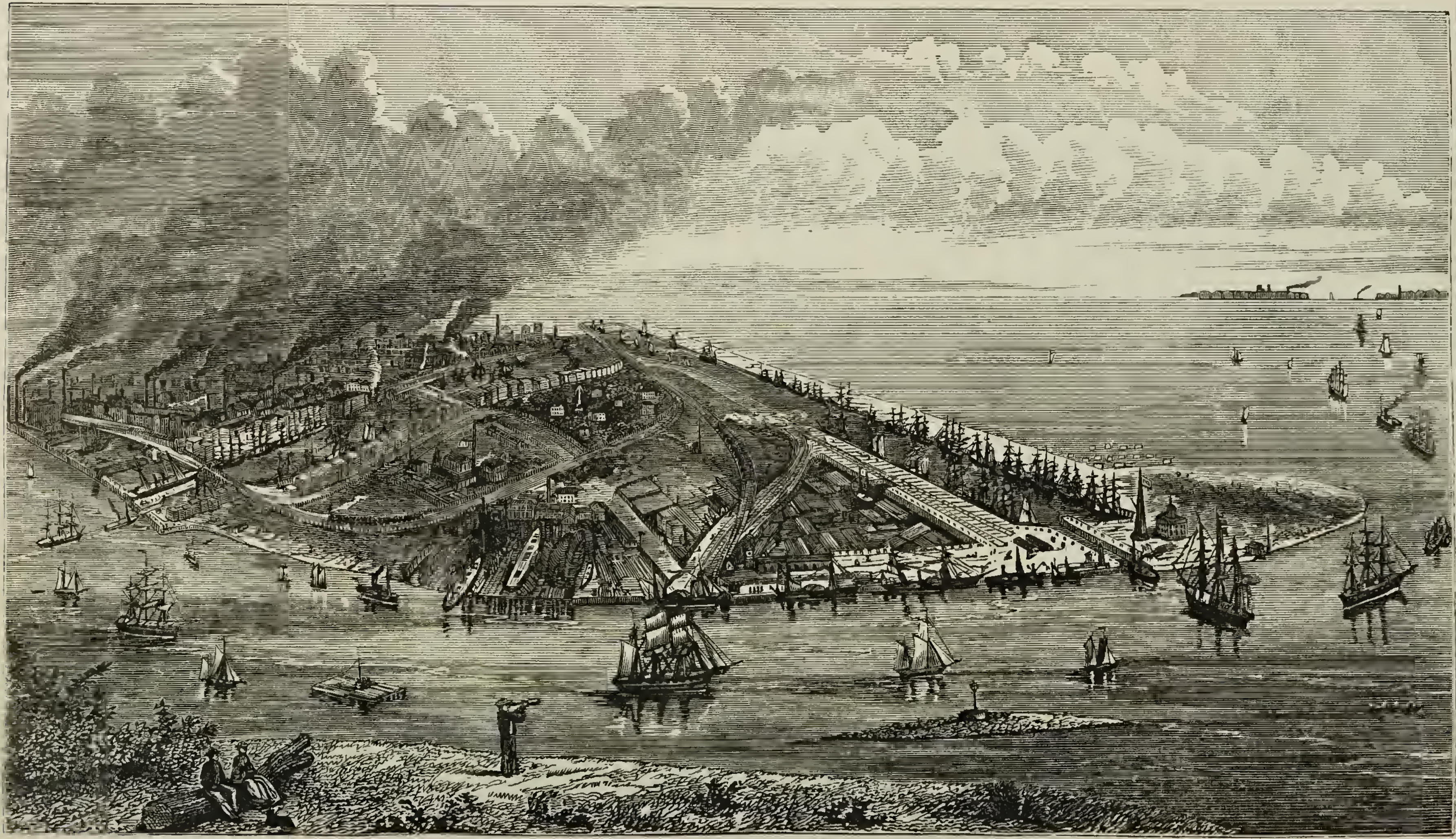

FIG. 218.—Barrow-in-Furness.—England.

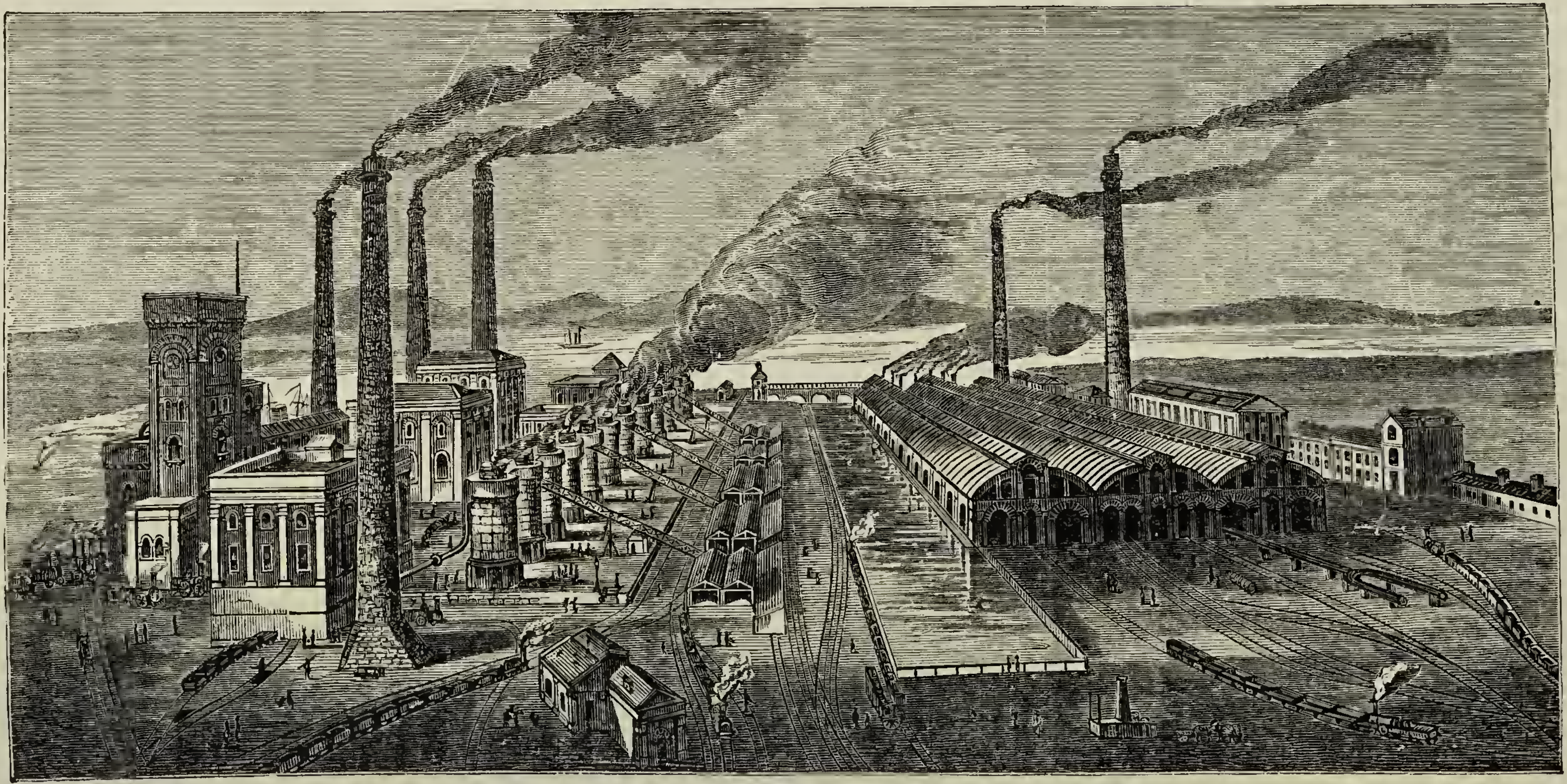

Fig. 219.—Bird's-eye view of the Barrow Hematite Steel-Works.

planned, light, airy, and convenient. The machinery is all well made, substantial, and of the most modern British designs. There were some places at which the improvements introduced by Mr. A. L. Holley into American practice could be adopted with advantage.

The iron from the blast-furnaces enters the steel-works at one end and leaves as finished metal at the other. The roll-trains are heavy, and are driven, in one case at least, by one of the Ramsbottom reversing engines, which have been received with so much favor in England.

386. The Cumberland red hematite is a very pure sesquioxide. The following analyses indicate its character.

These ores contain:

	Best.	Ordinary.	Lean.
Oxide	95.	78.61	61.30
Phosphorus	0.	.01	0.01
Sulphur	0.	.01	Traces
Silica	4.31	16.15	27.00
Alumina	0.07	1.67	2.76
Prot. manganese	0.04	.24	.24
Lime	0.34	.60	1.17
Magnesia	Traces.	.24	.65
Water	0.47	2.00	6.59
Total	100.23	99.53	99.72
Metallic iron	0.66	0.55	0.43

The Spiegeleisen used at Barrow is obtained from Germany and Sweden. The Swedish is considered fully equal if not superior to the German. The limestone is found in the neighborhood. The coke is Durham coke, and is brought across from Yorkshire at small expense.

387. Specimens of the steel made at Barrow were subjected to experiment by Fairbairn, who found it to have properties as recorded in columns A and B.

	A.	B.	C.
Specific gravity	7.754	7.795	7.785
Weight per square foot	483.70	486.40	485.50
Tenacity	80,905.00	72,195.00	89,504.00
Crushing strength	225,568.00	225,568.00	225,568.00
Tensile resilience	2,547.00	3,351.00	2,719.00
Crushing resilience	41,420.00	50,207.00	41,848.00
Modulus of elasticity	33,663,333.00	27,881,000.00	30,421,000.00
Co-efficient (tons) of transverse strength	4.50	3.90	5.35

The experimenter compares the Barrow steels with other Bessemer steels of well-known makers, which have the mean values given in column C.

A riveted girder, composed of a web 12 inches deep and ¼ inch thick, with flanges 5¼ inches wide, of angle iron 2½ × 2½ × ¼ inches and 13.9 feet between supports, deflected 0.1 inch under 5,000 pounds, 0.2 under 12,000, 0.4 under 26,000, 1 inch under 38,000, and broke after a deflection of 1.8 inches and under a weight of 49,544 pounds, yielding by tearing the lower flange. A similar girder gave way by lateral flexure under

AUTOGRAPHIC STRAIN DIAGRAMS OF METALS

PRODUCED BY THE BESSEMER & SIEMENS PROCESSES

as recorded by the Testing Machine of Professor Thurston.

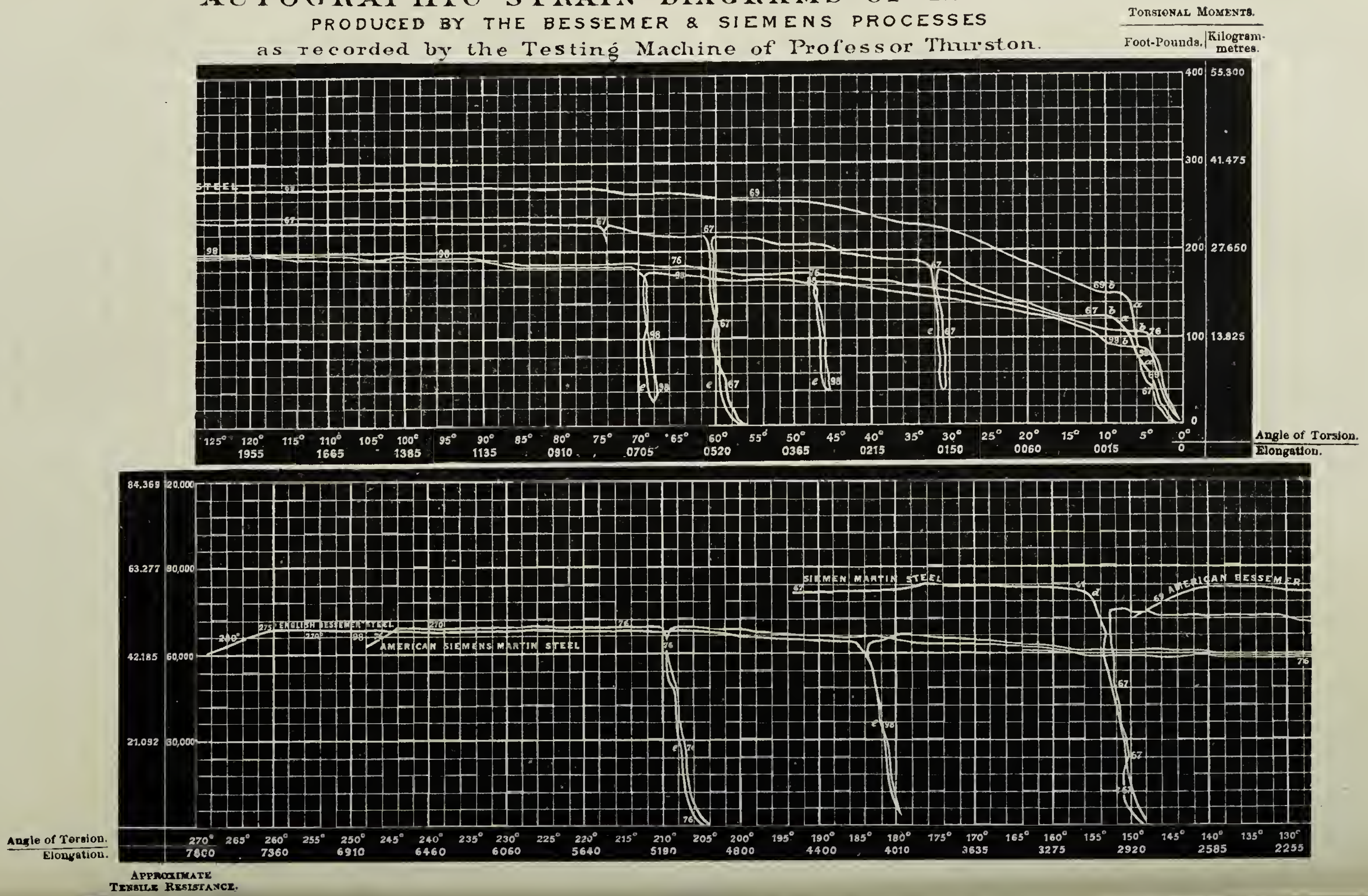

Fig. 330

about 30,000 pounds. These steel beams were pronounced by Mr. Fairbairn one-third stronger in resistance to deflection than the best wrought iron, and much superior in their resistance to impact.

588. This low steel is the best known material for rolled beams, and for built girders intended to resist either, or both dead load and impact. In ultimate strength the ratio of this Bessemer metal to good iron is as 1 to 0.652.

A collection of specimens of these steels has since been presented to the Engineering-Department of the Stevens Institute of Technology. Specimens cut from the head of a steel rail were subjected to test in the autographic testing-machine, and the strain-diagrams (of one of which Fig. 220, No. 98, presents a *fac-simile*) automatically recorded by the machine corroborate general testimony regarding the quality of the softer Barrow steels.

This specimen was cut from the head of a Barrow rail which had been bent up cold to an angle of 120° without cracking.

The elastic limit is seen to be moderately high, 28,000, indicating a combination of elasticity and good wearing qualities. The ultimate strength is about 70,000 pounds per square inch; the elasticity is uniform and the resilience unusually high.

In homogeneousness of structure, the metal is not quite equal to the other metals of which the strain-diagrams are given for comparison, but it is freer from internal strain, and consequently from inherent deficiency of stiffness, than are the others.*

389. THE CLEVELAND DISTRICT.—This iron-making district of Yorkshire is situated in the Northeast section of England, and is generally known as the Cleveland district. The principal seat of this industry is in the neighborhood of Middlesborough-on-Tees, and the ore is obtained from the Yorkshire hills a few miles from the river. This district has had almost as rapid a development as the Cumberland region. Its principal city, Middlesborough, was, like Barrow, a mere hamlet a quarter of a century ago, and, like Barrow, has now grown into a city containing over 25,000 people; and where there was then only an extended and barren moor, desolate and seemingly valueless, there are now more than a hundred blast-furnaces, many of which are larger than any yet built in any other part of the world.

It is in this district that builders of furnaces have exhibited the greatest intelligence and enterprise in pushing improvements to their practical limits, and a maximum of economy in production has been attained by the use of large furnaces and of heated blast.

390. At a former visit, in 1871, the writer examined these furnaces very carefully. The largest furnaces then built were a pair built for Messrs Cochrane & Co., which were 30 feet in diameter and 95 feet high,

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* See a paper by the author "On the strength, elasticity, ductility, and resilience of materials of machine-construction;" Transactions American Society of Civil Engineers; Van Nostrand's Engineering Magazine; Journal Franklin Institute, &c., 1874.

with a capacity of 30,000 cubic feet. These have since been lined and brought to a diameter of 27 feet, as it was found that they were too large to work satisfactorily. They were fitted with the Cowper hot-blast stove, heating the blast to a temperature of 1,400° F.

The furnaces of Messrs Gjers, Mills & Co., are 85 feet high and 25 feet in diameter of bosh. Their hearths are 8 feet in diameter and 8 feet high. The brickwork, the inner and outer stacks included, is made of Newcastle fire-brick, which is there less expensive than the ordinary building-brick generally used elsewhere. The body of the furnace is built up nearly in the form of a cylinder, tapering slightly as it rises, and is hooped with iron. In many cases furnaces are now incased with sheet-iron. At Middlesborough the foundations are made of concrete.

The temperature of blast usually carried is about 1,200° F., and the cast-iron stove with "pistol-pipes" is generally used.

The usual proportion of diameter to height of furnace is about 1 to 3, and of diameter of hearth to altitude about 1 to 11.

The blast is invariably heated, and a tall chimney is usually built to take away the products of combustion from the stoves and boilers. That at the above-described furnaces had a height of 110 feet. The area of heating-surface in the stoves was somewhat variable, but the best practice was claimed to give about 1,250 square feet per thousand cubic feet of blast per minute, reckoned by the capacity of the blowing-engines.

The furnaces of the Ferry Hill Company, which are a little way out of the city, are the highest in the district. They have a height of 102½ feet and a diameter of bosh of 27½ feet. They were claimed to have made iron more economically than any other furnaces in the shire, producing 550 tons per week with less than 500 tons of fuel.

At Spennymoor, near Ferry Hill, we found the furnaces of the Weardale Iron-Works—Messrs. Rogerson & Co.—and examined the plant with some care. The two blast-furnaces are each 85 feet high and 26½ feet in diameter of bosh, supplied with a blast of a temperature of 1100° F., and 3½ pounds pressure. The product was stated to be from 300 to 400 tons per week. The ore was a mixture of Cleveland, Weardale, and Spanish. The coke was very hard, resonant, and strong, and was used at the rate of 27½ cwt. per ton of iron made. The hoist was a water-lift. The stoves were of iron. The iron made here contains both sulphur and phosphorus in small quantities, but is very uniform in quality, even-grained, and strong.

The pig was decarbonized in 64 puddling-furnaces and worked into iron of all standard merchant sizes of bar and plate. The round iron runs from $\frac{3}{16}$ inch diameter to 8 or 9 inches.

391. The cost of the furnaces, of medium height, say from 75 to 78 feet, is not far from £16,000, including all the accessories of hot-blast apparatus, hoists, and kilns.

The ore used is a lean argillaceous oxide, which is found in the green lias of the Yorkshire range of hills. It is roasted at the furnaces, where it is dropped from the cars directly into the kilns, which are usually continuous in their operation. The fuel used in these kilns is frequently fine coal and "breeze," and the amount consumed in good work averages about a hundred pounds to the ton of ore. In calcination, the ore loses 25 per cent. of its weight, and then contains usually not much above 40 per cent. metallic iron. The composition of ore and of iron is as follows:

ORES.

Protoxide of iron	39.92	43.02
Sesquioxide of iron	3.60	2.86
Protoxide of manganese	0.95	0.40
Alumina	7.86	5.87
Lime	7.44	5.14
Magnesia	3.82	5.21
Potash	6.27	....
Silica	7.12	7.12
Carbonic acid	22.85	25.50
Phosphoric acid	1.86	1.81
Sulphuric acid	Trace	....
Bisulphide of iron	0.11	....
Water	2.97	3.48
Organic matter	Trace	0.15
Ignited insoluble residue	1.64	0.05
	100.41	100.61
Metallic iron	33.62	35.46
Authority	A. B. Dick.	A. B. Dick.

IRONS.

Carbon, (graphitic)	3.04	3.35
Silicon	2.73	1.57
Sulphur	0.04	0.04
Phosphorus	1.30	1.38
Manganese	0.38	0.07
Nickel Cobalt	....	....
Authority	Percy.	Percy.

The fuel used in these furnaces is Durham coke. It is very remarkable for its strength and hardness, which enable it to carry the burden of the highest of these immense furnaces. It contains from 92 to 95 per cent. carbon and 1 per cent. or more of sulphur. This impurity and the rather heavy proportion of sulphur and phosphorus in the ore unfit the iron produced for use where either steel is to be made or great strength demanded. The attempt has been made at Middlesborough to make steel, but unsuccessfully. The coke is made at the coal-mines to avoid increased expense of transportation. The process requires from two and a half to three days, and the product equals frequently about two-thirds the weight of coal charged into the ovens.

The limestone used as a flux is also obtained largely from the Durham district. It varies greatly in composition, the best containing 95 per cent. and upward of carbonate of lime, and the poorer containing less than 90 per cent., with a serious admixture of magnesia.

The common proportions of the charge are about 8 cwt. of ore, 2½ cwt. of limestone, and 3 cwt. of coke. The cinder produced is usually of a light greenish-gray color, strong, somewhat porous, and quite free from iron. An analysis given the writer at his previous visit gave 33 per cent. silica; 23 or 25 per cent. alumina; 30 to 35 per cent. lime; 2 per cent. or less sulphur; ½ per cent. oxide of iron, and the remainder consisted principally of magnesia.

392. The form of blowing-engine in general use is quite similar to that so frequently adopted in the United States. It has vertical cylinders, the steam and blowing cylinders in the same line and their pistons attached to the same rod. Those at Ferry Hill are of 10½ feet stroke, and the steam and blowing cylinders are respectively 67 and 130 inches in diameter. In some cases a peculiarity of general design or of valve-gear may be seen, but the usual practice and the best examples are not noticeably different from those of engineers in the United States.

393. The expense of making iron is less in the Cleveland district, notwithstanding the leanness of the ores, than in any other part of Great Britain or possibly of the world. The ore, as mined, contains, as a maximum, in selected specimens, but 45 per cent. of oxide, or about 30 per cent. metallic iron; the flux is usually somewhat refractory and is not exceptionally rich in lime. On the other hand the one great advantage possessed by iron-makers here is the very excellent character of a fuel which enables them to adopt the maximum size of furnace and temperature of blast which may be, on the whole, used with advantage. It is to these peculiarities, and to the boldness, skill, and experience of their blast-furnace engineers and managers, that their success is due.

The growth in size of furnaces may be seen by the following outline:

The first furnace built here, in 1851, by Messrs Bolckow & Vaughn, was but 42 feet high and of 4,500 cubic feet capacity.

The Clarence works, in 1853, built furnaces 48 feet high, and the largest, fifteen years ago, was but 58 feet high, and of 7,000 cubic feet capacity. Whitwell & Co. built a furnace, in 1861, 60 feet high; Bolckow & Vaughn, in 1862, constructed one 75 feet high and of 12,000 cubic feet contents, and Vaughn soon after ran up a furnace to a height of 78 feet; and the firm, in 1868, built a pair of furnaces of 96 feet height, and of a capacity, the one of 26,000 the other of 29,000 cubic feet. Mr. Cochrane subsequently built the Ormesby furnace of 41,000 cubic feet, and the Ferry Hill furnace of 103 feet height and 33,000 cubic feet capacity. No important increase of economy occurred with these larger sizes, although an increased yield is observable. In other districts furnaces which had been given great height, in imitation of the Cleveland furnaces, have been reduced to 55 and 60 feet height, as it was found that their contents could not sustain so great a burden.

At Cleveland the capacity now amounts to from 300 to 400 cubic feet per ton of yield per day. The conclusion of the most experienced iron-masters whom we met confirmed our own conclusion, that, although there is a certain height and proportional diameter of furnace which will be the practical limit as determined in each case by the character of the materials used, that limit is rarely approached until after an economical limit is reached, beyond which it does not pay to enlarge them.

Similarly, the benefit of increased temperature of blast reaches a working-limit within the temperature at which practical difficulties arise in elevating it. When all the escaping gases are thoroughly utilized in the hot-blast stoves and under the steam-boilers, a furnace will usually be found to work with satisfactory economy and without serious difficulty in keeping up, provided it has originally been well designed for its work and properly fitted up.

Cleveland metal sells in the markets at a price which ranges from 15 to 20 per cent. below the price of Scotch and Newcastle irons, but the profits to the iron-masters have always been satisfactory.

394. LANCASHIRE.—This coal-district contains a large number of collieries, of which no small proportion are worked out, and it is here that we are brought most strikingly into view of the possibility of a not distant time when Great Britain shall have exhausted her coal-fields, and with their loss have become a merely agricultural country. The depth to which these shafts are already sunk, even where the mines are still capable of yielding a large supply, is becoming a serious matter, both as affecting the cost of raising the fuel and of keeping the mines free from water, and as affecting the value of a day's work at depths at which the subterranean heat is sufficient to debilitate the workman and at which thorough ventilation becomes a matter of difficulty. The introduction of the pneumatic rock-drill may aid in this matter in a very important degree. By doing the work of several men, this machine permits the atmosphere of the mine to be kept wholesome with a less supply of air; its exhaust of pure air at every stroke at the very extremity of the working insures a certainty of a complete renewal of air, which cannot be attained by any other method; its exhaust of pure air is also rendered intensely cold by its great expansion, and it may be found, possibly, that mines may be worked at vastly greater depths than have previously been thought inhabitable. The great power of penetration—amounting to over 50 feet in ten hours, in some cases, in the hardest granite*—is evidently not the only recommendation of the rock-drill. These tools are used to some extent in England, but less than in the United States. The earlier forms introduced in this country, as the Burleigh and the Ingersoll, are successfully introduced into the market,

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* The rock-drill of Professor DeVolson Wood has accomplished this on several occasions, and has drilled 66 feet in limestone and 90 feet in magnetic iron-ore at Mineville, N. Y.

and the remarkably effective drill more recently introduced by Professor De Volson Wood, of the Stevens Institute of Technology, has now been patented in Europe, and its beautiful combination of theoretical with practical excellences, its strength and durability, ought to bring it rapidly into use.

Remarks similar to the above apply to the great coal-fields of South Staffordshire. The immense "ten-yard seam" is one of the interesting features of the district. It is usually worked by the "pillar and stall" method; but, when of exceptional depth, it is worked in two parts, called the top and the bottom workings. The pillars are usually about 25 or 30 feet square; the stalls are 150 feet square, the roof supported by four pillars, and the chamber separated by a wall 20 or 30 feet thick from the adjacent stalls. But little trouble is experienced from either fire or choke damp. Deaths occur from this cause in the proportion of about one man to 850,000 tons of coal raised. Near West Bromwich, this seam has been worked at a depth of 1,200 feet. In some parts of the field the receipts from sales have amounted to £20,000 per acre. Coal from this seam was used by Dud Dudley in 1620, and has always been in demand for manufacturing purposes. All of the South Staffordshire coals are of fine quality. The district also yields an argillaceous iron-ore, containing 40 or 50 per cent. of metal, from which is taken about 1,000,000 tons per year.

About 5,000-horse power is required to drain the mines, raising daily 220,000 tons at an annual cost of £125,000, amounting to about 3½*d.* per ton of coal.

There are about 550 collieries at work, raising 10,000,000 tons of coal, of which 9,000,000 goes into market. The district produces 855,000 tons of finished iron per year.

This is the oldest manufacturing district of Great Britain. The Romans worked the mines and made iron in the county, and it was here that Dud Dudley, the pioneer of modern iron-makers, did his work. In 1788, there were no furnaces here melting iron with charcoal, but there were nine using mineral coal. In 1806, there were 222 blast-furnaces in Great Britain, of which 162 were in blast, and 42 were in this district. There are now about 175 here. The larger make 250 tons of iron per week; the average size yields about 150 tons per week.

At Stourbridge, in Staffordshire, is raised the celebrated Stourbridge fire-clay. It has the following composition:

	Silica.	Alumina.	Prot. iron.	Lime.	Magnesia.	Potash.
Sample 1	59. 87	33. 49	3. 01	1. 42	0. 31	2. 21
Sample 2	67. 69	27. 91	2. 35	0. 63	0. 11	....
Sample 3	70. 32	26. 42	1. 04	0. 36	0. 43	1. 40

It makes excellent fire-bricks and crucibles, burns perfectly white, and makes a fine glass-house clay.

Stone, porcelain, and glass ware form an important class of Staffordshire manufactures. The potters consume nearly 200,000 tons of clay per year, and export wares of the value of £1,000,000. The Messrs. Chance, of Birmingham, make a large proportion of the finest optical glass in the world. They have supplied glass for all of our very large telescopes.

The whole district is alive with industry. The manufactures are of immense extent and variety. Birmingham is devoted to the manufacture of small articles chiefly, but their variety and importance make this one of the most interesting sections of the country to every stranger who is at all interested in such matters.

395. JAMES WATT & CO.'S SOHO WORKS.—At Soho, near Birmingham, James Watt, with his partner, Matthew Boulton, started the first steam-engine manufactory which ever existed. Watt, the mathematical-instrument maker, driven within the walls of the University by the trades-unions, who wished to prevent his practicing his trade, improved the Newcomen engine and made it the means of reclaiming the drowned-out coal-pits and iron-mines; but he could have accomplished little without the aid of Boulton, the Birmingham maker of toys.

The firm of James Watt & Co. and the Soho Works still exist, although the great founders have long since passed away.

The Soho foundery was completed and business was commenced within its buildings in 1796. Boulton was an active, enterprising, intelligent man, of great boldness and remarkable business capacity. He furnished the capital with which Watt developed his inventions. He was, however, a good mechanic also, and devoted himself to those departments of minor manufacture which brought wealth to Soho before the steam-engine in Watt's hands had begun to pay. He turned his attention to the production of mint-machinery, and Soho has furnished a large proportion of the mint-presses in use in Europe. A large amount of coin was minted at the foundery, and the firm still have their private mint, at which are made the coins of some of those nations, as Siam, which are not yet so far advanced as to have mints of their own. Watt's copying-machine was perfected at Soho, and a process of reproducing oil-painting, possibly a modification of the modern lithographic method, was commenced and worked, apparently with success, but was subsequently suppressed at the desire of Sir W. Beechey.

William Murdock, Watt's foreman and most efficient assistant, introduced the use of gas for illumination in 1802.

From 1797 to 1805 the coinage of copper at Soho amounted to 4,000 tons, valued at £800,000, for the British government alone, and immense quantities were struck off for the East India Company and for foreign nations. The amount coined from 1860 to 1866 is stated as about 3,500 tons, making over 600,000,000 pieces of coin. This early mint was pulled down in 1857, and in 1860 James Watt & Co. built the new mint, which is now at work. There have been sent out to other mints more than a hundred coining-presses.

The works cover ten acres of ground and have produced some 2,000 steam-engines, having a power of probably 300,000 horses. The great screw-engines of the Great Eastern, with steam-cylinders 84 inches in diameter and 4-feet stroke of piston, were built by Watt & Co. They are of above 6,000 horse power.

Visiting those works, so interesting from these historical associations, they were found to be rather pleasantly situated, and better planned than are the larger number of old British establishments of a similar character. The superintendent, Mr. Reed, was very courteous and attentive to his visitors, and kindly showed us every portion of the works. There were employed at the time of this visit about 800 workmen. The tools were usually old; some were built in the time of the great inventor, from Watt's own designs. He seemed to have been remarkably fond of worm-gearing; it was used on nearly all the boring-machines, both horizontal and vertical, and, on some large lathes, mortice-gearing was very generally used.

A large pair of compound marine-engines in the Napier style were in process of construction. Their surface-condensers were given a refrigerating area of about 2½ square feet per horse-power. Four large pumping-engines for the city of Buenos Ayres were the most novel of all the engines building. They were compound, and all steam-jacketed. The steam-jackets were formed by inserting a plain cylindrical casting, or bushing, within the main casting of the steam-cylinder, as is so usually done by British builders of marine-engines. A set of pumps for London sewage was an interesting design. The mint-machinery made here is of excellent proportions and of beautiful finish. The mint, which, as already stated, forms a part of this establishment, strikes 100 coins per minute.

In the boiler-shop several "Martin boilers," similar to those so extensively used in our own Navy during the late war, were in course of construction for the British admiralty. Riveting was done both by steam and by hand. Hand-riveting was sometimes practiced in heading up snap-headed rivets. The boiler-work was usually well done. The snap-head is much oftener used in Europe than in the United States. It is somewhat more troublesome to make by hand than the conical head, but it is stronger.

James Watt & Co. make their own files, not so much with the intention of saving expense as to secure precisely the quality which they desire. They also forge their own bolts and nuts. We saw nowhere in Europe machines designed for this kind of work which appeared as effective as those of Abbe, and of one or two other American inventors.

En route between Yorkshire and the Midland district we passed through that section of the country which has always been well known to engineers and manufacturers in the United States as the seat of manufacture of Low Moor, Bowling, and other brands of the best Yorkshire iron.* At Bowling, the refuse material from the mines has accumulated until it has formed a mountain of no small size.

The Leeds Mercury gives an account of these works, from which we learn the following facts:

The Bowling Iron-Works were originated so far back as the year 1780, although the actual smelting of ores did not commence there until 1788. The works owed their origin to Mr. John Sturges, of Sandal, near Wakefield, who saw that the minerals in the vicinity of the works were of the proper character for the manufacture of first-class iron. Subsequent events have amply justified the choice of the site. In point of antiquity, however, Bowling has to yield to the works of Kirkstall Forge, which claims not only to be the first establishment that used the rolls for slitting iron into nail-rods, but claims also to have carried on that process at so remote a period as 1594. Until the Bowling Works were started, however, the special iron for which Yorkshire is now celebrated was unknown. The first furnace at Bowling was blown in 1788, and is still in being, with the initials "S. S. & Co." inscribed upon its front. This furnace is strong even now in its old age, having the appearance of a fortification that has suffered a violent attack from the enemy, but has strength enough remaining to resist a further onslaught.

The extent of the Bowling Company's estate is exceedingly large. Its collieries extend five or six miles in various directions. In all, the company has 42 pits, worked by over 60 steam-engines, which engines are supplied with steam by 81 steam-boilers, of from 10 to 50 horse-power each. There are tram-ways from all the pits direct into the iron-works, the entrance for the whole of the tram-ways being on the higher ground toward Dudley Hill. The tram-ways cover a total distance of 21 miles, and are worked by means of wire-ropes. With the exception of the limestone, which is procured from the neighborhood of Skipton, nearly all the mineral used in the manufacture of iron at the Bowling Works is obtained from their own mines, and, of course, none of this mineral is permitted to go elsewhere than to the foundery.

Referring to the quality of this valuable mineral, the late Mr. Wilcock said: "The substratum around Bowling is part of the most extensive and valuable coal-field in England, stretching from Derby or Nottingham to this district, a distance of 60 miles, and ranging about eight miles broad." The seam of coal called the "better bed" is one of the valuable elements necessary for the production of the best quality of iron. The stone wears a dark-brown appearance, and yields about 32 per cent. of iron. Both coals are caking coals, and moderately hard. This is the same bed of minerals that the Low Moor and Farnley Iron Companies have at command, their several mineral rights extending to points at which they meet. This is the bed that all the best Yorkshire brands are made from—brands which command far higher prices in the market than the general makes of iron. A Bowling boiler-plate will fetch from £27 to £44 per ton, according to the weight, 2½ cwt. plates being the minimum, and 7 cwt. and upward being the maximum price; while good Staffordshire plates can be got for about £14 or £15 per ton. This is sufficient to show the great difference that there must be between the Yorkshire iron and the ordinary iron.

In its general features Bowling Foundery is much like other iron-founderies. Here and there are to be seen improvements which are in advance of what is to be seen at other iron-works, but, on the other hand, it is evident that in some things the Bowling Company have been reluctant to make changes. Within the last four or five years,

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**Analysis of Bowling irons.*

		Pig metal.	Puddled iron.
Pig metal.	Carbon, graphitic	3.155	0.272
	Carbon, combined	.581	
	Silicon	1.346	0.000
	Sulphur	.070	trace
	Phosphorous	.635	0.000
	Manganese	1.472	0.000
Metallic iron—	Puddled		99.727
	Pig		99.903

however, many very extensive alterations have been effected, and improvements are at the present time in rapid progress.

There are three entrances to the foundery, the principal one being in Bowling, Buck Lane. Near the entrance gate-way stands a grim, residential-looking building, which has been used as offices in recent years. On the upper ground are received the minerals as they come fresh from the earth. This is the starting-point of the foundery. Here the various elements necessary to the making of iron are brought together and laid in heaps. Numerous trains of coal and iron-stone stand about on the rails, ready for being cast into one or other of the various fires that are burning and smoldering everywhere. There are long lines of cinder ovens and heaps, where the coal is being converted into coke. There are 14 iron-stone kilns, where the iron-ore is roasted. The ore is thrown into the kilns along with an admixture of black bed "breeze." It crumbles away until it reaches the bottom of the kiln, when it is carted away to the furnaces. After the iron-stone has gone through the kiln, the coal through the ovens, and the limestone has been broken into manageable pieces, they are put into capacious iron wagons. There are six cold-blast furnaces at Bowling, five refining-furnaces, 21 puddling-furnaces, and 40 heating-furnaces. The amount of iron made per week is about 360 tons. The largest of the blast-furnaces is a recent addition to the works, and is on an improved principle. It is made of iron, and is of a circular form. The other blast-furnaces are of the ancient kind. The height of the new furnace is 55 feet from the hearth to the filling floor, it being 13 feet higher than the old ones. There is no great gaping orifice exhibited here, as in the other furnaces, all the heat and gas being utilized. The minerals are raised to the top of the furnace by means of a lift. The top is closed in with a circular, cone-like iron covering, which is lifted by a hydraulic lever, and when the cavity round the edge of the cone has been filled with the due proportions of coke, iron-ore, and limestone, the lever is lifted, and down the whole mass descends into the furnace. The gas that is carried off from this furnace is conveyed to the boiler-house adjoining, and serves to feed three boilers and a half—*i. e.*, seven fires. This furnace is certainly one of the most interesting objects to be seen at the Bowling Iron Works.

There are thirteen steam-hammers at the Bowling Iron Works, some of them of a very heavy, ponderous kind. It is the custom to give a premium to the puddlers who produce the best specimens during a turn.

The new plate-mill, built in 1873, is a very noticeable place. It is worked by a pair of reversing engines, on the locomotive principle, by which the necessity of heaving the plate over the top roll of the rolling-machine is obviated. It is stated that in this plate-mill wider plates can be rolled than at any other works in England.

In making what are known as the Bowling iron weldless tires, "stampings" only are used. First, the "bloom" is taken, and a hole about five inches in diameter is made in the center. When this has been done, the ring of iron that has thus been formed is fastened to the back of an anvil, where a flange is raised by hammering it, care being taken by constant rotation to get all the parts evenly worked. The ring then assumes something of the shape of a proper tire, and is finally perfected by being submitted to a rolling process.

The steel-works were commenced in 1866. Siemens's gas process for melting crucible-steel is in operation.

Boiler-making has always been a great feature of the Bowling Iron Works, and a large new boiler-shop has been lately erected, which is capable of turning out from two to three boilers per week. All these shops are fitted up with movable cranes that adapt themselves to any piece of iron or any elevation.

In the making of weldless hoops for boilers there are a great number of workmen employed.

The model-shop is one of the finest shops of its kind to be found. It is a large brick building, two stories in height, and many thousands of models are kept. They are all catalogued, so that any model that is wanted can be found immediately. Among wheels of all sorts and sizes, giants and liliputians, is to be found the original model from which the first wheel for Blenkinsop's locomotive was cast. This has a label attached to it, informing visitors what a very distinguished model it is.

There are altogether between 2,000 and 3,000 work-people employed in the foundery and collieries of the Bowling Iron Company. The total horse-power of the engines employed about the iron-works is about 900, and in providing steam for these engines there are 38 boilers.

At Low Moor, the works seemed still more numerous, and the pile of refuse was even larger. These works have been celebrated for many years for the excellent quality of their boiler-plate and other wrought-iron products. Visiting Low Moor, we found in blast six blast-furnaces of about 40 feet height, working a native clay iron-ore, with coke as fuel and a cold blast. There are employed in the mines and mills about five thousand people, who produce 500 tons of finished iron per day. The pay-roll amounts to about £6,000 per week.

All pig worked in the mills is refined by melting down in open furnaces, using coke as fuel, and running out into flat cakes, which are broken up for the puddling-furnaces. There are six of these refining-furnaces and thirty-five puddling-furnaces. All iron goes from the puddling-furnace to the hammers, of which there are twenty, of several sizes and of various kinds. One steam-hammer will work the puddle-balls of seven furnaces. The manager states that the old style of helve-hammer is generally preferred for this work. It gives invariably the heavy blow required to force the cinder out of the sponge, and the hammer-man *cannot* modify the blow to keep a defective ball in shape. The billets made are piled and again hammered before rolling.

Each furnace usually works off nine heats per day, and ten have been made. The heaviest hammer weighs 12 tons.

The plate-rolls are reversed by a clutch, which is used whenever the weight handled exceeds about 800 pounds.

Nearly all furnaces in this neighborhood are open-topped and are worked with cold blast. At night the whole country seems lighted up by the flames from them and from the numerous coke-ovens scattered thickly in all directions.

396. SCOTCH IRON MAKING AND WORKING.—There is little that need be said of Scotch methods of iron-making. We found nothing novel in Scotch practice, either in the building or the working of furnaces. They are never of large size, are usually open-topped, and, when hot blast is used, it rarely exceeds a temperature of 700° or 800° Fahrenheit. The fuel used is raw coal, and its friability limits the height of furnaces usually to less than 60 feet. The whole district contains something less than a hundred and fifty furnaces, and the production is estimated at about 1,500,000 tons annually, the average product being about 200 tons per week per furnace, and rarely much exceeding that amount.

The ore is the remarkable "blackband," and contains 10 per cent. carbon, as an average for rich ores, and the proportion sometimes rises to above 20 per cent. The ore is roasted before charging into the furnace, and it is sometimes found that it contains fuel enough for its calcination without the use of additional fuel. The amount of fuel used in the furnace is, however, very large, probably double that used per ton of iron made in the Cleveland district, and an additional expense is incurred for cheap fuel with which to make steam and to heat the blast.

The pig-iron made is usually a dark, soft, easily-fusible foundery-metal. The grades of Glengarnock, Gartsherrie, Coltness, Eglinton, and one or two others are well known in the Eastern iron-markets of the United States. In the Western States the phosphoritic ores of Tennessee and other districts are capable of supplying quite as good metal for all those purposes for which a fusible, free-flowing iron is required.

The forge-grades are worked into a moderately good but rather cold short iron, and, with the irons from Cleveland, supply the Glasgow and Clyde markets with a considerable proportion of their ship-plates.

397. GLASGOW, AND IRON-SHIP BUILDING.—The receipt of communications from Vienna, immediately after landing at Glasgow *en route* from the United States, indicating a desire that we should reach the former city in time to take part in the preliminaries of jury-work, hastened us away from this interesting district before we had time to do more than take a rapid glance over the ground and make a very brief examination of the work in progress in the city and on the banks of the Clyde, and pay a short visit to the University of Glasgow.

The business of the ship-builders was not as prosperous as it was found at the earlier visit to this place, in 1871. We counted about fifty iron vessels, nearly all steamers, in the yards of builders on the river between Govan and the city, and probably nearly an equal number were in progress in the yards nearer the mouth of the river. All business had received a check which was very seriously felt, and no new contracts were offered or taken. The uncertainty of the direction of the movement of prices, the recent rise in cost of material, and the embarrassment caused by the strikes which had recently taken place here, had completely stopped work, both here and in the districts supplying coal and iron. The work on hand was nearly all on old contracts, and very little new work was anticipated until the cost of both labor and stock should be reduced to a point which would enable building to be resumed with moderate profit.

The consequences of this state of business were exceedingly unfortunate. The unemployed workmen were either lying idle at home, indulging in dissipation, to which they had been before unaccustomed, or were leaving the neighborhood. The result is, as a matter of course, moral depreciation and physical suffering, as well as loss of skill to the workmen and the loss to the country of its best talent and of considerable wealth.

The increase of Glasgow in wealth and population has been very rapid during the last twenty years, and the population now amounts to 600,000 people. The proximity of districts supplying coal and iron, her position at the head of navigation on the Clyde, and, above all, the intelligence, thrift, and energy of her people, have been the prominent causes of her prosperity.

The enterprise and intelligence of the people of Glasgow have been well illustrated in the manner in which they have improved their harbor.

The prosperity of a city is seldom dependent upon local natural advantages alone; and the proximity of the iron and coal producing districts of Scotland, her experience in manufacturing, and the advantages arising from the fact that Glasgow is the birthplace of modern British marine engineering, could hardly have given that city her present position as the second in population and the first in the realm in several branches of manufacture, had not her people, long ago, had sufficient foresight and energy to expend enormous sums in the improvement of the water-approaches to the city.

Two hundred years ago the port of Glasgow was on the Ayrshire coast. To-day, ships drawing 23 feet of water can reach the city-wharves.

The work of maintaining and improving the ship-channel below Glasgow is, by act of Parliament, placed in the hands of the Clyde Trust Company, which is controlled by Glasgow capital. This company have expended in this work about $28,000,000, and they are still engaged in this great work, and are removing a million tons from the channel annually. They are permitted, by a special act, to lay a limited tonnage-tax on all vessels, and their income from this source has risen from $286,487, in 1840, to $493,346, in 1870. The registered tonnage of vessels at the port of Glasgow now exceeds 5,000,000 tons annually.

398. Iron-ship building.—This industry, although its history dates back many years, is really but of very recent general introduction. At the beginning of the present century, Lord Dundas built an iron boat for the Caledonia Canal, and occasionally an iron vessel was built in succeeding years. The "Great Britain," built nearly thirty years ago, was the first large sea-going vessel ever constructed, and the success of that venture probably determined the rapid introduction of iron hulls which has subsequently taken place.

The advantages possessed by iron over wood are very great, and the disadvantages, although in some respects serious, are, nevertheless, not sufficient to counterbalance them. The value of iron in ship-building is now universally recognized.

Wood has the advantage, with us, of being well adapted to the resources of our naval and private shipbuilding-yards. The coppered hull is less liable to become foul at sea and to impede the vessel. Minor repairs can be made promptly and at little expense. For naval vessels, its penetration is less liable to prove a source of danger when shot strike beneath the water-line, and, aside from the presence of water-tight bulkheads, it is perhaps safer when struck by a ram or by a torpedo. It has the disadvantage of being vastly less strong and in being quite incapable of giving that strength of joints and at points of contact of distinct members given by iron, and it is necessary to make the hull very much heavier than in iron. These facts place an early limit to the increase of size of vessels which is so remarkable a feature of recent naval architecture. It decays very rapidly, particularly if the timber is unseasoned, and is exceedingly treacherous. It absorbs water after a time, and the vessel becomes slower and of deeper draught, and loses cargo-carrying capacity equal in amount to the weight of water absorbed.

In naval vessels, except in the case of teak, it injures the armor-plating by promoting oxidation, both by the direct action of the acids contained in the sap and by the galvanic action induced by the voltaic influence of the copper-sheathing. When iron is near or in contact with the sheathing, it fouls even more rapidly than an iron vessel. Its seams are liable to start in a heavy sea or on striking, even though without great violence, upon shoals or rocks, and, in bad weather, the seams at the stern are peculiarly liable to become loosened by the vibration of the screw as it leaves the water and is suddenly plunged in again by the pitching of the vessel. In iron-clads it is impossible to caulk seams covered by plating, and the defect of strength already noted prevents preservation by removal from the water, either in dry-docks or in slips. The liability to loss of wooden vessels by fire is a very serious objection to them.

Iron has the advantage of being more readily procured, promptly, and of any specified quality for work of any size or kind. It may be examined in the structure with convenience and with confidence that its condition may be accurately ascertained. It may be given any form that may be desired, and without loss of strength. It may be united firmly by welding or by riveting, and the strength of the joint may be known with an approximation to correctness. It makes a lighter as well as a vastly stronger hull, is capable of being put into place with any desired rapidity, and the vessel, once constructed, has vastly more durability than a wooden ship. Repairs are less frequently required and can be more thoroughly made than in wood. The shaking of the screw or the shock of a projectile is not likely to start seams or to produce other than local injury, and even the iron vessel is driven on shore it is less certain to go to pieces than the wooden vessel. The "Great Britain" lay several weeks on the coast of Ireland, exposed to the storms and waves of the Atlantic, and was finally brought off, and is still a sea-going steamer. The convenience with which efficient water-tight compartments may be fitted is a very essential and peculiar advantage in iron shipbuilding. Freedom from danger of loss by fire, convenience of cleaning when foul, and unlimited endurance of the greater portion of the structure are important advantages.

The disadvantages attending the use of iron are the rapid fouling of the hull, except under peculiarly favorable circumstances, the cost of docking and frequent repainting, and, more serious than all else, the danger of the loss of iron ships by changed course, produced by the variation of the compass from local attraction. They are also peculiarly liable to injuries of kinds which are very difficult to repair promptly when in collision with other vessels or when struck by shot.

An iron vessel may safely be given much greater length and much finer lines than a wooden ship, and if laid up the hull and machinery can be preserved indefinitely without serious injury.

Formerly a considerable amount of iron shipbuilding was done in other parts of Great Britain, and the yards of the Tyne and the Mersey still retain some business, but the Clyde has acquired by far the greater part of the trade of the country.

In 1870 about 180 vessels, having an aggregate registry of nearly 200,000 tons, were built here. In the year 1869, the number built was 180 and the tonnage 160,000, almost all steamers.

In 1873 there were built 194 vessels, having 261,500 tons total burden; and for 1871 and 1872 the figures were 196,200 and 224,000 tons, respectively. These vessels cost about £16 per ton as an average price for slow steamers to carry freight, and from £20 to £25 per ton for fast transatlantic passenger-ships.

399. THE FAIRFIELD WORKS, formerly Elder & Co., and earlier, Randolph, Elder & Co., were among the pioneers in the introduction of the now familiar iron steamer with compound engines and the peculiarities of engineering practice which distinguish them.

Among the successful vessels built by them nearly twenty years ago were the steamers of the Pacific Steamship Company, plying on the western coast of South America. They formerly built engines having high and low pressure cylinders whose pistons were coupled to cranks set opposite each other. They now build the so-called "Napier style," in which the cranks are placed at right angles, and which are thus made as simple in form, as light, and as cheap as the earlier style of low-pressure engine which they displaced. The firm have now the largest establishment on the Clyde, and can lay down fourteen ships at one time. A fine new engine-building establishment has recently been completed, and has capacity sufficient for the employment of between two and three thousand men. The building is very large and is well constructed The light tools are all placed on galleries which run across the building at the lines of posts carrying the roof. Many of the largest and most successful transatlantic steamers have been built here. Among them. are several vessels of the National and the Anchor lines.

The Italy is one of the most successful of the former. That vessel makes her passages in from ten to twelve days, on a consumption of from 500 to 600 tons of coal, and an indicated power of about 2,000 horses. The vessel registers 3,700 tons.

The Bolivia, of the Anchor line, is 410 feet in length, of 40 feet beam, and of 4,250 tons burden. The displacement is nearly 8,000 tons.

These long ships are rapidly coming into favor. They carry their cargoes at comparatively small expense, make their trips with regularity and at high speed, and are found to behave well in the worst of weather. Such vessels, with machinery disabled and once in the trough of the sea, are less easily cared for than shorter ships, but they ride well with the sea on the bow, pitch and "scend" very little, and seem to roll very little, if any, more than vessels of the older proportions. Where not built of good iron and where the work on the hull is not well done, they are very apt to start the vertical seams amidships and to become leaky, or even to founder, as one or two have actually done. When this happens, however, it is good evidence of bad material or bad workmanship, or both; it is the evidence of faults of construction which are inexcusable. Messrs. Elder & Co. have always been well known for good work. They have employed as many as 6,000 men.

Nearer Glasgow, and on the Govan side of the river, is the establishment of Messrs. *J. & G. Thompson.* They have built the excellent steamers of the Cunard line. They can employ from 2,000 to 2,500 men. During the late civil war, this firm built some of the fastest and most successful of the blockade-runners.

An older and a well-known firm, having its works still farther up the river, is that of Messrs. *R. Napier & Sons.* The machine-shops of the firm are in the city. The ship-yard is quite large and is well arranged. The firm has for many years been one of the few firms intrusted with the building of the naval vessels of Great Britain. Its founder, Sir Robert Napier, was one of the earliest and greatest of the steam-engine-builders of Great Britain. It is here that the Napier style of compound engine, which is now almost exclusively adopted, was first built.

400. A few firms on the other British estuaries are doing work which should interest every visitor from the United States. On the Tyne, below Newcastle, are the works of the Messrs. *Palmer & Jarrow.* It was here that some of the latest and finest steamers of the Guion line were built. The Palmer Shipbuilding Company have a very large establishment. It includes several blast-furnaces, a large rolling-mill, machine-shops and founderies, and a ship-yard. The number of men employed in busy times was stated at 6,000. This firm also have built some naval vessels, among which the most interesting are the sister-ships Triumph and Swiftsure. The iron hull in these ships was covered with a wooden sheathing, over which the copper sheathing was fastened. This plan is not likely to be frequently adopted, for the reasons already given in the comparison of the relative advantages and disadvantages of wood and iron.

Some shipbuilding is also done on the Wear, the Tees, and the Mersey.

At Birkenhead, opposite Liverpool, are the works of the Messrs. *Laird*, who are best known to Americans as the builders of the Alabama, the confederate cruiser which, after a long career of successful privateering, was finally sunk, after a short fight, by the United States steamer Kearsarge. The firm had, in former times, been very prosperous, but its most successful days are probably gone by.

401. The relative merits of the compound engine and the engine of older type have already been considered in that portion of the report on

the Vienna Exhibition which treats of marine-engines. A good marine steam-engine of the form which was considered standard fifteen or twenty years ago, having low-pressure boilers carrying steam at 20 or 25 pounds pressure as a maximum, expanding twice or three times, and having a jet-condenser, would require about 30 or 35 pounds of feed-water per horse-power per hour; substituting surface-condensation for that produced by the jet brought down the weight of steam used to from 25 to 30 pounds; increasing steam-pressure to 60 pounds, expanding from five to eight times, and combining the special advantages of the superheater and the compound-engine with surface-condensation, has reduced the consumption of steam to 20, or even, in some cases, 15 pounds of steam per horse-power per hour. Messrs. Perkins, of London, guarantee to furnish engines capable of giving the horse-power with a consumption of but one and a quarter pounds of coal. Mr. C. E. Emery, who is one of the most successful designers of compound engines in the United States, reports the United States revenue-steamer Hassler to have given an ordinary sea-going performance which is probably fully equal to anything accomplished abroad. The Hassler is a small steamer, of but 151 feet length, 24½ feet beam, and 10 feet draught. The engines have steam-cylinders 18.1 and 28 inches diameter, respectively, and of 28 inches stroke of piston, indicating 125 horse-power; with steam at 75 pounds pressure and at a speed of but 7 knots, the coal consumed was but 1.87 pounds per horse-power per hour. This is the best performance of which we have record.

402. THE BRITISH NAVY.—The International Exhibition of Vienna gave the visitor no idea of the relative power of European navies, and it requires a visit to the dockyards of Great Britain, and to the great steam-engine-building establishments which furnish machinery for the royal navy, to give a conception of the magnitude, cost, and strength of the navy of this most powerful of all maritime countries. The little model of a naval engine exhibited in Group XIII at Vienna gave as little idea of the character of naval machinery as did all other naval exhibits of other classes of naval material.

The British navy now contains between six hundred and seven hundred vessels. All recently built are iron steamers, and about forty of them are iron-clads. The modern iron-clad is necessarily an iron vessel. No structure of wood, or any material of less strength than iron, could be made capable at once of sustaining the immense weight of armor now considered necessary and the tremendous strain of the 8,000 horse-power or more which drives them at such high speeds as fourteen or fifteen knots an hour, or of giving anything like this speed with the weight of machinery which could be carried. Of these iron-clads a large majority are broadside vessels, but the usual form, as now built, is the turret iron-clad, or monitor type, first introduced into the United States Navy when Capt. John Ericsson designed, and Mr. T. F. Rowland built, the Monitor which saved our fleets from destruction by the Merrimac.

The thickness of armor carried varies from 4½ inches in the ships built after the Crimean war to 24 inches in the later ships, backed usually with a considerable thickness of teak. The heaviest plating on broadside vessels is that of the Hercules and the Sultan, which has a maximum over the battery and at the water line of 9 inches. These vessels have the heaviest armament, although not the heaviest guns. They carry eight 18-ton rifles of 10-inch bore, two 12-ton rifles of 9-inch caliber, and four 6½-ton rifles of 7-inch bore. These are all of the kind made at Woolwich, and closely resemble the Armstrong gun. Their structure is somewhat peculiar, and their lightness in hull and machinery is as remarkable as their strength and power.

403. This extreme lightness in machinery has been the result of very careful and skillful designing, of intelligent construction, and of care in the selection and use of material. British builders had, until after the introduction of these later types of vessels of war, been distinguished rather by the weight of their machinery than for nice calculation and proportioning of parts. Now the engines of the heavy iron-clads are models of good proportions, excellence in materials, and of workmanship which are well worthy of study. The weight per indicated horse-power has been reduced from 400 or 500 pounds to less than half that amount within the last ten years.

This has been accomplished by forcing the boilers—although thus, to some extent, losing economy—by higher steam-pressure, a very much higher piston-speed, reduction of friction of parts, reduction of capacity for coal-stowage, and exceedingly careful proportioning.

The reduction of coal-bunker capacity is largely compensated by the increase of economy secured by superheating, by increased expansion, elevation of piston-speed, and the introduction of surface-condensation. A few vessels have been fitted with compound engines.

404. The improved structure of both hull and machinery may be best illustrated by an account, in some detail, of the iron-clad Monarch, the fastest and one of the most formidable of the vessels designed by Mr. E. J. Reed, formerly the chief constructor of the British navy. This vessel is a turreted iron-clad, built in competition with the designs furnished by the Lairds for that unfortunate ship the Captain, subsequently lost by capsizing in a gale of wind in the Bay of Biscay.

The writer was sent by the Navy Department to inspect the Monarch on the occasion of her arrival in the United States with the body of the distinguished philanthropist George Peabody, and was then and subsequently able to secure very complete data of construction and performance,* the most essential of which are here given.

405. CLASSIFICATION OF WAR-VESSELS.—It is only recently that the attempt seems to have been made to determine a classification of war-vessels and to plan a naval establishment which shall be likely to meet

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* For a more complete description, with illustrations, see a paper by the writer in the Journal of the Franklin Institute, 1870.

fully the requirements of the immediate future. It has hitherto been customary simply to make each ship a little stronger, faster, or more powerful to resist or to make attack than was the last. The fact that the direction of progress in naval science and architecture is plainly perceivable, and that upon its study may be based a fair estimate of the character and relative distribution of several classes of vessels, seems to have been appreciated by very few.

In the year 1870 the writer proposed* a classification of vessels other than torpedo-vessels which has since been also proposed in a somewhat modified form by Mr. J. Scott Russell.† The writer then remarked that the increase so rapidly occurring in weight of ordnance and of armor and in speed of war-vessels would probably soon compel a division of the vessels of every navy into three classes of ships, exclusive of torpedo-vessels, one for general service in time of peace, the others for use only in time of war.

"The first class may consist of unarmored vessels of moderate size, fair speed under steam, armed with a few tolerably heavy guns, and carrying full sail-power.

"The second class may be vessels of great speed under steam, unarmored, carrying light batteries and as great spread of canvas as can readily be given them; very much such vessels as the Wampanoag class of our own Navy were intended to be—calculated expressly to destroy the commerce of an enemy.

"The third class may consist of ships carrying the heaviest possible armor and armament, with strongly-built bows, the most powerful machinery that can be given them, of large coal-carrying capacity, and unencumbered by sails, everything being made secondary to the one object of obtaining victory in contending with the most powerful of possible opponents. Such vessels could never go to sea singly, but would cruise in couples or in squadrons. It seems hardly doubtful that attempts to combine the qualities of all classes in a single vessel, as has hitherto been done, will be necessarily given up, although the classification indicated will certainly tend largely to restrict naval operations."

The introduction of the stationary, the floating, and the automatic classes of torpedoes and of torpedo-vessels has now become accomplished, and this element, which it was predicted by Bushnell and by Fulton three-quarters of a century ago would at some future time become important in warfare, is now well recognized by all nations. How far it may modify future naval establishments cannot be yet confidently stated, but it seems sufficiently evident that the attack, by any navy, of stationary defenses protected by torpedoes is now quite a thing of the past.

It may be perhaps looked upon as exceedingly probable that torpedo-ships of very high speed will yet drive all heavily armored vessels from the ocean, and complete the historical parallel between the man in armor of the Middle Ages and the armored man-of-war of our times.

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* Journal Franklin Institute, 1870. H. B. M. S. Monarch.

† London Engineering, 1875.

406. The following is a brief description of the most important features of construction of the Monarch, above referred to, and of her machinery, armor, and armament:

The hull of the Monarch is of iron, and is built on what is called by Mr. Reed the "combined longitudinal and bracket-plate system."

Its length is 330 feet, beam 57½ feet, and depth about 36 feet. The mean draught is 24½ feet, measured tonnage 5,102, and displacement 8,100 tons. The iron is all of good quality, having a tenacity of over 50,000 pounds per square inch and extensibility of nearly one-fifth. A double bottom extends under the whole space occupied by engines and boilers, and up as high as the lower edge of the armor; the bow retreats as it rises above water, and below the surface it is well strengthened to serve as a ram; the stern-overhang is brought down to the water-line and armored, in order to protect the rudder-head.

The vessel is ship-rigged, carrying about 21 square feet of canvas to each square foot of midship-section, giving a large aggregate but small proportional spread of sail. The outside plating of the hull varies in thickness from 1⅛ inches in the garboard-strakes to $\frac{13}{16}$ and ¾ on the lightest portion of the side.

The armor-plating is 7 inches thick along the water-line and 6 inches on exposed portions of the hull that are included between two armored athwartship's bulkheads, which inclose the bases of the turrets and the "funnel." The other parts of the hull are unarmored, except that casemates are raised forward to protect two guns pointing ahead, mounted under the forecastle, and aft also, to protect a single gun firing directly astern.

The armor is backed by 12 inches of teak, and supported by the inner 1½ inches iron skin-plating in two thicknesses of ¾ inch each. The inner skin is stiffened behind the armor by the ship's frames, 10 inches deep and 2 feet apart, and also by longitudinal frames riveted to the skin outside and imbedded in the backing, but not in contact with the armor-plating.

The athwartship armored bulkheads have 5-inch armor, backed with 10 inches of teak and a supporting inner skin.

The double bottom is made water-tight, and is divided into compartments like the hull itself; it is also provided with means for filling and emptying each of its compartments as may be necessary to ballast or to trim the ship; its greatest value consists in the safety which it affords against loss of the vessel from injury to the outer skin by the bow of an enemy, by torpedoes, or by striking a rock.

Heavy stringer-plates are worked on each deck, and the spar-deck is wholly of ½-inch iron, with a covering of wood. Above the double bottom, the ordinary transverse framing is adopted. A wing-bulkhead lends additional security by strengthening the hull and resisting shot capable of penetrating the side armor.

The hull is divided transversely by several water-tight bulkheads. One of these bulkheads is placed near the bow, in order that, should the bow be strained or torn open by a collision, the ship may still float safely; another is built at the screw-shaft stuffing-box near the stern, two inclose the engine-room, two others inclose the boiler-space, and another divides it equally; others inclose the magazine and the holds. All openings in these bulkheads have water-tight sliding iron doors fitted.

There is no external keel, its absence being pretty nearly compensated, perhaps, by the "bilge keels." A "balanced rudder,"* similar to those so long used in our own Navy, is fitted, and its weight is taken on a set of conical rollers at the rudder-head. Double chain-riveting is employed in butts and laps throughout the hull. The weight of the hull without armor is given at 3,674 tons, and the weights carried at 4,632 tons. The load-draught is 22½ feet forward and 26¼ feet aft. The cost of the hull was not far from £300,000.

407. The turrets of the Monarch are 26½ feet in diameter, plated with 8-inch iron, backed with 10 inches of teak and an inner 1¼-inch iron skin; they are strengthened by girders in the same manner as the side armor of the hull.

On the side in which the ports are cut, the outer plating is 10 inches thick; these plates are 19 feet long.

The turrets rest upon 32 conical rollers, bearing on a circular bed-piece fitted upon the main deck; they rise through the upper deck to a sufficient height to allow the line of fire of their guns to clear that deck, and are only armored where exposed above the upper deck.

The turrets are turned either by hand-power or by a pair of engines of about 10 inches diameter of cylinder and 12 inches stroke of piston. The turrets may be turned completely around in slightly more than a half minute. The pilot-house or "conning-tower," as it is called, is separate from the turrets, and immediately forward the funnel, an arrangement vastly less convenient in action than that adopted in our monitors. It has no sight-holes, but a reflecting mirror may be used above its open top, to obtain a view of the enemy; otherwise the head must be raised above the protecting shield.

The guns are carried 4 feet above the level of the spar-deck, or 16 feet above the water. The bulwarks are hinged, and in action are let down out of the way of the guns.

The armament of the Monarch consists of seven guns, two twelve-inch rifles in each turret, two seven-inch rifles in the forward casemate firing ahead or on either bow, and one seven-inch rifle in the after casemate pointing astern.

The twelve-inch guns weigh 25 tons each and throw shot weighing

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* The balanced rudder was used many years ago on the ferry-boats built under the direction of Robert L. Stevens, for the ferry between New York and Hoboken. It is also used on the fastest iron-clad yet designed, the Stevens Iron-clad Battery.

600 pounds with an initial velocity of 1,212 feet per second and an energy of 6,145 foot-tons, the charge of powder weighing 70 pounds. At 70 yards they are capable of driving their shot through 13½ inches of iron; their range at 10° elevation is 4,000 yards, or 2¼ miles, and at the proving-station a maximum range of 5½ miles has been obtained.

The turret-guns cannot be trained directly forward or right aft, being restricted in lateral training by the forecastle and other obstructions; the forward turret has been trained to within 19° of the line over the bow, while the after-turret guns train within 14° of a line running aft with the keel.

The seven-inch guns weigh 6½ tons each, and, with their regular charge of 22 pounds of English L. G. R. powder, throw a shot weighing 115 pounds, with an initial velocity of 1,425 feet per second and an energy of 1,650 foot-tons, this energy becoming reduced at 1,000 yards to 1,140 foot-tons. They are capable of penetrating nearly 9 inches of iron.*

All of these guns are of the regular Woolwich pattern, consisting of an inner tube of "Firth steel," re-enforced by two iron cylinders or bands shrunk one over the other. The twelve-inch guns are rifled with 9 grooves, making one revolution in 50 feet. The shot from the seven-inch rifles turns once in 20½ feet. The twelve-inch guns have a preponderance of 6 cwt. and the seven-inch guns of 3 cwt.

The ports in the turrets are cut very small, and, in consequence, a very novel method of obtaining elevation and depression of the turret guns is resorted to. The carriages of the guns are of iron, very similar in form to those used in our service. The compressors are made like those which were years ago fitted to heavy guns in our monitors by Captain Ericsson, consisting of a set of timbers lying under the carriage parallel with the slides of the gun, which are simultaneously clamped by a single motion of the compressing-gear, the friction between the beams and the jaws of the clamps resisting the recoil.

The device for elevating and depressing the guns referred to above consists of an arrangement of screws and hydraulic cylinders by which the gun is raised bodily in its carriage to obtain depression or dropped to obtain elevation. It requires five or seven minutes to raise the gun from the extreme of 15° elevation to the other extreme of 7° depression.

408. The engines are of the "back-acting" or "return-connecting-rod" type, steam-jacketed, and with surface-condensation, built by Messrs. Humphreys, Tennant & Co.

They have cylinders of 120 inches diameter, 4 feet 6 inches stroke of piston; their nominal horse-power is 1,100, and they have worked up to more than 8,100 indicated horse-power.

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* The following formula was constructed by the writer as approximately determining penetration: With Palliser chilled shot, $P = \sqrt{\frac{W\ V^2}{400{,}000\, d'}}$ where P = penetration of armor-plate in inches. W = weight of shot. V = its velocity on striking. d = its diameter.

The main valves are the common double-ported slide, balanced by a ring on the back; they are worked by a link-motion. The balance-ring moves with the valve, the wearing-surface being upon the valve-chest cover.

The expansion-valve—a gridiron-valve driven by an independent eccentric—is rendered adjustable by a half-link.

The steam-chest cover and cylinder covers are steam-jacketed. The main links are of the solid or "sector-bar" pattern, and give perfect satisfaction.

The outboard-cylinder heads are fitted with stuffing-boxes to accommodate 20-inch half-trunks, which it has been found necessary to add, in consequence of the fact that the great pistons cannot support their own weight—8 tons each—without seriously injuring the cylinder. The cross-head is fitted with "slipper-guides."

The surface-condensers are arranged, as is very usual in English engines, with vertical tubes $\frac{5}{8}$ inch diameter, 6 feet long, water outside and steam within; they contain 16,500 square feet of condensing-surface, equal to about 18$\frac{1}{3}$ square feet of surface to each foot of boiler-grate surface, or equal to about two-thirds the heating-surface. The vacuum obtained during a run down Chesapeake Bay was 27$\frac{1}{2}$ inches, as noted by the author, without using the jet injection, which is also fitted.

The main links are moved by a pair of reversing-engines mounted on the platform over the large engines; reversing occupies about fifteen seconds.

All the work is well done; very little, however, is highly finished.

The engines drive a two-bladed Griffith screw of 23$\frac{1}{2}$ feet diameter and 26 feet 4 inches mean pitch, expanding 5 feet. Its apparent slip is about 9 per cent., and it works with very little shake; it does not lift. A "separator" is attached to the steam-pipe near the engines. The crank-shaft journals are 3$\frac{1}{2}$ and 4$\frac{1}{2}$ feet long, and usually run without water, unless at full speed; the lubricant is Rangoon oil. The cranks carry heavy counterbalances, and at 40 revolutions, the highest number made under our observation, the engines turn their centers very smoothly.

The boilers are of the horizontal tubular kind, and have 20,900 square feet of heating-surface, 3,600 feet of superheating-surface, and 900 feet of grate-surface, or 27.2 square feet of total heating-surface to the square foot of grate. The boiler-tubes are 2$\frac{1}{2}$ inches by 8 feet; the superheating-tubes are 4 inches diameter by 2$\frac{1}{2}$ feet long. The dampers are so arranged that the gases may be sent either through the superheaters or to the smoke-pipe direct. The "funnel" is oval in section, with a cross area of about 125 square feet, or one-seventh the grate-surface. The superheating-surface is said to be ample, and the draught, which at full power is urged by blowers forcing air into the boiler-room, is all that is desired. The coal-bunkers are behind and at either end of the boilers, and the coal is transported without difficulty in large buckets, carrying 400 pounds each, which are suspended from a carriage running on an overhead tramway.

The ashes are thrown overboard by a steam-jet which acts like the steam-jet pump which is sometimes fitted on board steam-vessels as a bilge-pump. It is said to work well.

The engines and boilers occupy a length in the ship of 135 feet and a breadth of 45 feet. The following are their weights:

	Tons.	Cwt.	Qr.	Lbs.		Tons.	Cwt.	Qr.	Lbs.
Engines	318	5	2	5¼	Spare articles and gear.	52	9	3	4½
Boilers	355	19	3	22¾	Water in boilers	159	11	3	23
Screws	14	19	0	6½	Water in condensers	45	0	0	0

The total of all weights in the engineer's department, exclusive of 600 tons of coal and inclusive of bunkers, floor-plates, and fittings, is 1,136 tons.

The engines and boilers and all their appendages were built, placed in the ship, and the cost of steam-trials defrayed by the contractors for the sum of £66,500, an extremely low price when compared with the expense of building machinery in this country, but not so surprising when it is known that the best class of mechanics are paid but seven or eight shillings per day in England, and the cost of stock is pretty closely proportioned to the prices paid for labor.

409. The performance of the Monarch is satisfactory under sail or steam. When under sail she carries 20° weather-helm with the screw dragging, but with the propeller disconnected it reduces to 7°. Though carrying but two-thirds the amount of sail that is usually given men-of-war, she has made eleven knots under sail alone. The Monarch is a remarkably steady ship, dry in the heaviest weather, yet pitching very little; her maximum roll is stated at 21°. The guns were worked without serious inconvenience during a gale in the Bay of Biscay, when no one of the half-dozen broadside iron-clads in company could fire a gun.

Under steam, and on the measured mile, with a displacement of 8,070 tons, midship section 1,208 square feet, and mean draught of 23 feet 1 inch, a speed of 14.937 knots on an average horse-power of 7,843—maximum 8,139—was attained, the steam-pressure being 31½ pounds, revolutions 63.61—maximum 65—and coal-consumption about 2⅔ pounds per horse-power per hour. The formula—

$\frac{\text{“}V^3.\ \ M\text{”}}{I.\ H.\ P.}$ gave a co-efficient of 513.4, and $\frac{\text{“}V^3\ \ D^{\frac{2}{3}}\text{”}}{I.\ H.\ P.}$ gave 171.

On a six-hours' trial the results were as follows: Speed, 14.715 knots; I. H. P., 7,470; steam-pressure, 30.58; revolutions, 62.67; coal per H. P. per hour, 2.789; co-efficients of performance, 515.3 and 171.6. These co efficients are low, but that fact is not discreditable to the designer, as it was considered advisable to sacrifice something in this respect, in order to obtain a cheaper and "handier" ship, and the lines were therefore made rather full.

The Monarch can steam 125 hours at 12½ knots; 210 hours at 11 knots, or 475 hours at 8 knots nearly, running distances of 1,600, 2,310, and 3,800 knots before consuming her 600 tons of coal. Acting as a ram, the Monarch has an "*energy*" of 33,415 foot-tons at 12½ knots, 25,200 foot-tons at 11 knots, and 13,040 foot-tons at 8 knots, or a destructive power, at those speeds, equal to 5½, 4, or 2 Woolwich 600-pounders simultaneously discharged against the same spot.

The magnetism of the Monarch has now become permanent in amount and distribution, with a *maximum* deviation of the standard compass of 10° 30′, and the course may be laid with all the certainty that could exist in any wooden ship.

In conclusion, although we may agree with the designer of the Monarch, who, after the designs had been issued and the ship laid down, stated his conviction that "no satisfactorily designed turret-ship with rigging has yet been built or even laid down," and though we may go even further and assert that, very probably, none ever will be designed it must be admitted that the Monarch is a very effective and powerful fighting machine. Her speed is greater than that of any war-vessel in the world, with the exception of one or two broadside-ships recently built in England; her armor, though not impenetrable, will yet enable her to fight a considerable time in an action in which she may usually choose her own position, without probably receiving vital injury; her guns have the greatest penetrating power of any yet worked on shipboard, and they can be worked in any weather, while their height above water gives them advantages, in other respects, that should not be underestimated. Her power as a ram is immense, and her construction is such as will enable her, with tolerable safety, to make use of that power. Her spread of sail, though comparatively small, will enable her to circumnavigate the globe, if required, independent of steam. On the other hand, the ship is large, costly to build, and expensive to keep afloat; she is not impenetrable to the heavy guns of the present day, to say nothing of those next year or of the next decade; she is seriously restricted in lateral range of guns, carries comparatively little coal, and is liable to become completely disabled by the fouling of the screw by rigging shot away in action, a danger shared, of course, by all masted vessels. In our harbors, her great length and depth would be fatal disadvantages.

410. BRITISH NAVAL POLICY.—Great Britain has a definite naval policy which is carried out with tolerable consistency. In her liberal action and intelligent appreciation of the importance of the improvements which are continually being made in naval engineering, including architecture and ordnance, that nation exhibits a marked contrast with the United States. The British navy is greatly increased by the construction of new vessels, and it has been the declared policy of the admiralty to build annually about 20,000 tons, of which about 10,000 or 12,000 tons are to be armored. While keeping up her fleet, however,

the fact that we may be approaching a complete revolution in naval methods of warfare is not lost sight of, and the administration is not only steadily and carefully following a system of experiment with the various forms of torpedoes, but officers of the navy and government officials in foreign countries are continually watching naval movements in those countries, and, in some cases, officers are detailed to the special duty of observing and reporting upon everything of interest and all novel and promising improvements. So intelligent a policy must inevitably produce satisfactory results in increasing the efficiency and the economy of naval administration.

411. LATER VESSELS.—Until the Monarch was built, there were no monitors in the British navy. Since the successful performance of that and of other turreted ships, several very formidable ships have been laid down.

The most powerful of these iron-clads are the Devastation, the Thunderer, and the Fury; and the latest and most formidable of all is the Inflexible. The former are 285 feet in length, 62½ feet beam, and 26 draught. They are registered as of 4,406 tons burden. Their side-armor is 12 inches thick in single thickness along the water-line and on breastworks and somewhat thinner below water. The armor rests on teak-backing 18 inches thick, and an inner skin 1½ inches thick. The deck rises 4½ feet above water. The turrets are 31 feet in diameter, armored with 14-inch plates on the side through which the ports are cut, and 12 inches on other parts, backed with 15 and 17 inches of teak on an inner 1¼-inch skin. The bow is strengthened to be used as a ram. These vessels carry each four 35-ton twelve-inch rifles in two turrets, at a height of twelve feet above water. The shot weigh over 600 pounds, and are propelled by 100 pounds of powder, like that used in the 70-pound cartridges of the Monarch's guns. The vessels have a speed of 12½ knots per hour, and carry 1,600 tons of coal, a quantity sufficient for ten days' steaming; they have twin-screws, driven by engines of 800 nominal horse-power, collectively.

The Inflexible, the most powerful British iron-clad yet designed, has recently been laid down. This vessel is 320 feet long, of 75 feet beam, and about 25 feet draught, displacing 11,000 tons. The hull is somewhat similar to that of the Monarch in construction, but "low steel" is used in the frames. The battery is to consist of four 81-ton guns of the Woolwich pattern, each throwing a shot weighing a half ton, with, probably, an initial velocity of nearly 1,500 feet per second. Two are mounted in each of the two turrets, and the line of fire of all can be directed directly forward, directly aft, or on either beam. At certain angles the turrets come in line, and the sweep of one pair of guns is interrupted for a limited angle of training. This peculiar arrangement is secured by placing the turrets one on each side of the immensely wide deck, and the one abaft the other, so that, when firing on the one beam, the line of fire of the one turret is ahead of the other, and, while firing on the other beam, the line of fire of the second passes aft of the first turret. Firing ahead or astern, the removal of the turrets from the center-line of the ship gives them ample clearance. The turrets are protected by armor 2 feet in thickness, and are carried above a rectangular box 110 feet long, also armor-plated, and protecting the machinery and other essential portions of this fighting machine. The remaining portions of the vessel, forward and aft the armored bulk-heads which terminate this fighting house, are unarmored, but are divided into numerous compartments by water-tight bulk-heads. The armor is backed by 17 inches of teak. The "ram" extends 15 feet in advance of the bow. Deck-houses extend along the middle line of the vessel and between the fore and aft lines of fire of the guns. In these are accommodations for the crew. The engines are expected to develop over 8,000 horse-power and to drive the ship 14 knots, or nearly sixteen and one-half statute miles, an hour. The coal-bunkers will store 1,200 tons of coal, which will suffice for five days' full steaming, carrying the ship something over fifteen hundred miles, or, at 10 knots, across the Atlantic, leaving a reserve in the bunkers. As the later British ships have usually, on trial, been found to come well up to the estimates of their designers, this vessel will probably prove by far the most formidable vessel afloat. The only defect is in speed. The Monarch has steamed 14.9; the Wampanoag class of the United States Navy and the iron-clad designed by Robert L. Stevens and reconstructed by General McClellan and Mr. I. Newton will steam about 17 knots at load-draught.

The cost of the Inflexible is stated at between £500,000 and £600,000.

412. Sir Joseph Whitworth & Co., machinery and gauges.—The establishment of Sir Joseph Whitworth & Co., at Manchester, is among the few well known to American engineers.

Sir Joseph Whitworth was one of the first to introduce fine workmanship, accurate fitting, and precise measurement into the manufacture of tools and general machinery. Many years ago he constructed measuring instruments capable of indicating dimensions correctly within the ten-thousandth of an inch. He introduced systems of screw-threads and of gauges, which are now very generally adopted. The accuracy of his work may be imagined when it is stated that a set of Whitworth gauges was furnished the Stevens Institute of Technology from which any combination of sizes may be selected and they will be found to be equally perfect fits if introduced together into a ring which precisely fits over the larger gauge of which the diameter is equal to the sum of the diameters of the combination. Warming a ring-gauge slightly, the plug-gauge of corresponding dimension will fall freely through it; warming the plug and leaving the ring at normal temperature, the former will refuse to pass through the latter.

Messrs. Wm. Sellers & Co., who introduced this system of work into the United States, make similar gauges.

In many respects the styles of the tools made by these two firms and their methods of work resemble each other closely, and, excellent as is the work of the Whitworth Company, the American firm will not suffer by comparison. The remarks already made in reference to the machinery of Sellers & Co. will well apply here.

Messrs. Whitworth & Co. were the first manufacturers in Europe to adopt the Allen engine; it was brought to their notice by Mr. Charles T. Porter, who also introduced it on the continent.

Sir Joseph Whitworth has long been engaged in the manufacture of a peculiar form of ordnance, and has succeeded in obtaining results, on trial, which have not been equalled by the Armstrong, the Woolwich, or any ordnance yet introduced.

Its efficiency is largely due to its general form, its peculiarities of rifling, and the method of its manufacture, and, also, in great degree, to the wonderful endurance of the peculiar metal used in its construction.

413. WHITWORTH ORDNANCE.—The Whitworth ordnance has a power of penetration and a range exceeding other guns by probably 30 per cent. The maker claims, under some conditions, a superiority of 50 per cent. The fact that the British government has persistently refused to adopt, or even countenance, this system is one of those singular instances of wilful disregard of proven facts, or of official indifference to public interests, which it is difficult to account for, except on the supposition that private prejudice or private interests have been permitted to control the action of the departments. The result is unfortunate for Great Britain, but it may prove fortunate for her enemies.

The Whitworth gun is a rifle, now usually constructed of what the inventor terms "compressed steel," having a bore of hexagonal section, and throwing a projectile of the form of a hexagonal prism with conoidal or ogival ends, and of great length and weight in comparison with the projectiles used with other ordnance of equal size of bore.

The powder-charge is very large, even for this weight of shot.

The advantages possessed by the Whitworth form of rifling are: the ease and accuracy with which it can be produced in the manufactory; the great extent of bearing-surface, and consequently the slight wear and small loss by windage due to such area of rubbing-surface; the great strength secured to resist stripping of either shot or bore, and the facility with which it can be applied in construction of ordnance of any form or of any size.

The shot has, after a long series of experiments, been given a length of from three to four diameters, and the solid shot are given the conoidal form at each end. Shell are made parallel at the back end, to give them capacity for heavy bursting charges, and some sacrifice of range is thus made.

In 1871, a little 12-pounder Whitworth rifle, with a shot weighing 17¼ pounds and a charge of R. L. G. powder of 4¼ pounds, was fired at an angle of elevation of 33°, and attained a range of six and one-sixth miles.

Whitworth uses a flat-headed projectile in attacking armor-plate. This form will not penetrate thicker metal, when striking perpendicularly, than the shot with rounded head; but it will readily enter at angles of inclination which would invariably cause the latter to glance, and it will enter water and will penetrate under water. With the submarine gun proposed by Fulton, and but recently brought forward in modern shape, this form of projectile and the powerful gun from which it is fired are likely to prove essential elements of success.

A Whitworth 9-inch gun, with a charge of 50 pounds of powder behind a steel shell 3½ diameters long and weighing 404 pounds, drove its shot through three 5-inch iron plates and two 5-inch layers of iron cement, at 200 yards, the shell remaining in the target, with the ends protruding, front and rear. This is the most extraordinary case of penetration which has come to the knowledge of the writer.

These guns are manufactured very readily by modern methods, and there is no objection to their adoption on the score of economy. Their ammunition is cheaply made, and can be produced in large quantities, when demanded by the exigencies of war, promptly and at comparatively small expense. Whitworth estimates the time of fitting the rough casting to gauge, and turning it out ready for use, at 12 minutes, and the expense at less than threepence. Allowing for the difference in value of British coin and the depreciated paper-currency of the United States, the probable cost in this country may be estimated at about 6 cents.

In proving his guns the maker has sometimes adopted the novel expedient of securing the projectile in the gun and firing a diminished powder-charge behind it, permitting the gases to escape only by the vent.

The Whitworth breech-loader is another interesting product of the ingenuity of this great mechanic. It has a strong, easily fitted, and heavy breech-plug, is easy-working, and can be handled with great rapidity. One of these guns, throwing a solid shot weighing twelve pounds, four diameters long, and a charge of 2¼ pounds of R. L. G powder, with an angle of elevation of 40°, attained a range of 10,600 yards. It penetrated a 3-inch armor-plate at 200 yards, although the plate was inclined at an angle of 45°, and the shell was found imbedded 5 feet in the sand behind the target. The Whitworth gun has given better results than the Woolwich gun where the latter have 25 per cent. greater nominal weight of shot. The difference is even greater between small sizes. The 3-pounder Whitworth has equalled the 6-pounder Woolwich.

In putting the gun together Sir Joseph Whitworth dispenses entirely with the rude and usually awkward and hazardous process of shrinking the cylindrical "rings" upon the core, and adopts the more mechanical and satisfactory plan of turning and boring the parts to an exact fit, and forcing them into place by means of the hydraulic press. The hydraulic press is also used by Whitworth in forging the parts of the gun as Haswell uses that machine in forging the details of locomotive-work. The writer found the first-named using this method in 1870, and is uncertain to whom to give credit for the earliest introduction of the process into regular work.

In making shot and shell, Whitworth uses a molding-machine, and has succeeded in making such smooth and accurate castings that they can be used without loss of time or money in tool-dressing. They are, when of iron, cast of Pontypool (Welsh) white iron, which chills well and makes remarkably smooth and solid castings.

The following list of sizes and prices was furnished the writer at an earlier visit.

FIELD-GUNS.

Size of gun.	Weight.	Price.
3-pounder	315 lbs.	£40
6-pounder	630 lbs.	65
9-pounder	945 lbs.	85
12-pounder	1,260 lbs.	100

NAVAL ORDNANCE.

20-pounder	$18\frac{3}{4}$ cwt.	£160
32-pounder	30 cwt.	320
70-pounder	$75\frac{1}{2}$ cwt.	600
7-inch	7 tons.	950
8-inch	$10\frac{6}{20}$ tons.	1,400
9-inch	15 tons.	1,800
11-inch	27 tons.	3,200

In the year 1870 the writer examined the principles, the design, and the methods of manufacture of the Whitworth ordnance, and made a report* on the rival systems of Great Britain, at the request of the Admiral of the Navy, exhibiting its superiority to the other systems of ordnance then known, and urging its thorough and immediate experimental examination and provisional adoption. There seems no reason to doubt the correctness of the conclusions then arrived at. The system is philosophical, mechanical, effective, and economical.

414. COMPARISON OF WHITWORTH AND WOOLWICH SYSTEMS OF ORDNANCE.—As then stated, the objections to the Woolwich system are:

(1.) The use of a combination of steel and iron or of any two metals is objectionable when, as is to-day the case, a single metal may be employed without special difficulty.

(2.) The numerous welds required in building up guns of forged coils are so many weak points in the structure, and their presence is to be deprecated, no matter how skilful the smith who makes them.

(3.) The material itself, although the best of forged iron, is by no means the strongest material that can be obtained.

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*Report of the Secretary of the Navy, 1870, p. 172, *et seq.*

(4.) The heating of the bands preparatory to shrinking them on the gun unavoidably oxidizes their surfaces to a greater or less extent, and this layer of oxide must prevent metallic contact between the two surfaces.*

(5.) The impossibility of adjusting accurately the amount of force with which the bands will seize the barrel of the gun entails a possibility of loss of strength from either too great or too little strain; of this fact our experience during the late war with Parrott guns is good evidence.

(6.) The repeated heating and cooling of the metal while the gun is under construction weakens it and lessens its elasticity and resilience to a serious extent.

Whitworth avoids these objections—

(1.) By the use of a single metal of extraordinary strength and resilience.

(2.) By the use of cast-metal instead of welded up bars and coils.

(3.) By using the strongest and most ductile metal yet known in the arts—his "compressed steel."

(4.) By making such mechanically perfect fits of the bands that the hydraulic press may, with a given and safe pressure, just force them fully home, giving a uniform and firm grasp, which makes the gun act like a solid mass in resisting internal strains.

(5.) This method of adjusting the force with which the inner barrel is grasped enables the proper strain to be applied without danger of either overstraining the band or leaving it so loose that the strength of the gun is endangered by loss of its support.

(6.) The gun being made of a cast metal, is given its shape with a single cooling from the molten condition.

The advantages of the form of the bore and the proportions of gun and of projectile have already been considered.

This subject may yet be found one of vital importance to the country, and particularly to the naval branch of the service, and the writer is compelled, no less by that public spirit which should influence every citizen than by that personal interest which he retains in the service with which he was for so many years connected, to present it at some length and to urge its consideration. His experience and judgment both as a civilian and as a naval engineer unite in dictating this action.

415. WHITWORTH'S COMPRESSED CAST STEEL.—The remarkable metal used by Whitworth for his ordnance and for such constructions as demand material of exceptional strength was first publicly described by its manufacturer several years since, and was first experimentally used by him nearly twenty years ago.

In some directions, progress in engineering is limited by the strength

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* Mr. Hitchcock proposes to the United States Ordnance Department to avoid this difficulty by the ingenious expedient of heating in the neutral or deoxidizing flame of a gas-furnace and of forging without removal from the heating-chamber.

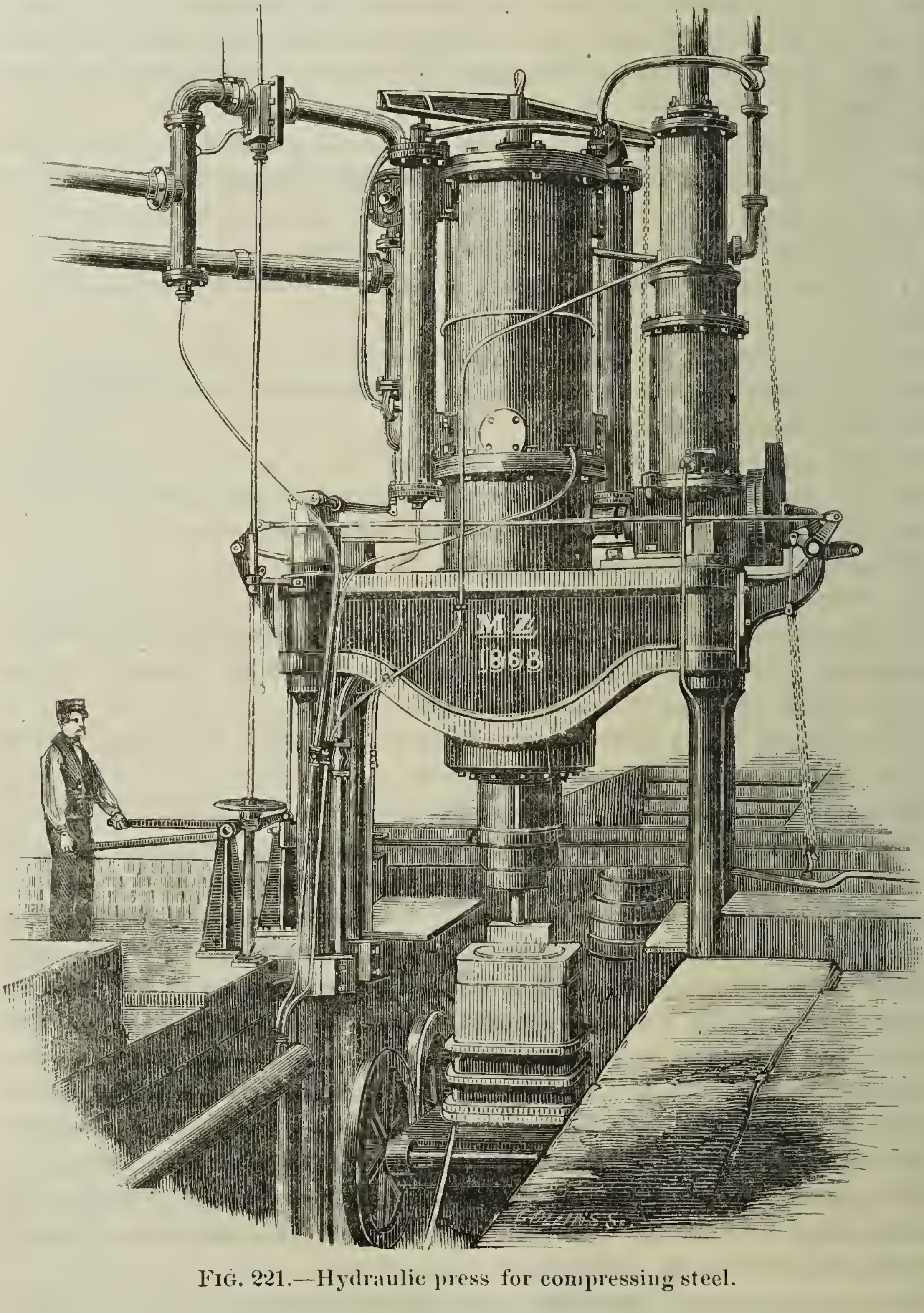

FIG. 221.—Hydraulic press for compressing steel.

and toughness of the material available. Where a combination of strength and lightness is essential, as in marine steam-engines, or where increasing the amount of metal is of no assistance beyond a certain limit in resisting strains tending to produce fracture, as in hydraulic presses, and especially in ordnance, the production of an improved metal is the essential step to further advance.

As has been already stated in another portion of this report, the several grades of steels are the strongest, the toughest, and the most ductile of the metals used in the arts. But the steels are subject to the very serious objection that castings made of them lose these distinguishing characteristics of the worked metal. Poured into the ingot-molds or made into castings, they are found to be porous and comparatively heterogeneous in texture and to be weak and brittle. It has not been found possible to remove the gas the occlusion of which produces these effects. Whitworth long ago adopted the very simple but perfectly effective expedient of subjecting the ingot or the casting, while still molten, to the tremendous pressure of the hydraulic press. Although a simple expedient, it has required a considerable amount of experiment and ingenuity to produce this "compressed steel" with uniform success. Success was, however, attained, and Whitworth has used the material for all of his recently-built ordnance and for apparatus requiring to be made of exceptional strength. It has now been introduced on the Continent—in France by Messrs. Révollier & Co., of St. Etienne, and in Austria by the Neuberg works. The latter establishment exhibited, at Vienna, samples of this steel of unusual beauty and excellence. The enterprising editors of London Engineering had photographs taken of the specimens of compressed and of uncompressed metal, from which the engravings given below were made, and were reproduced by the Iron Age, of New York.

Fig. 221 shows the form of press used in their production. The ingot-mold is placed on a carriage mounted on rails leading from the converters to the press. When the metal is poured from the ladle into the mold, the latter is rapidly transported to the press and subjected to a pressure of from 500 to 700 tons while solidifying. Sir Joseph Whitworth uses still a higher pressure, 2,500 tons, and even proposes to use a press of a capacity of 8,000 tons. With this press the pressure will be 15 or 20 tons per inch, and no metal can probably be used for ingot-molds except the Whitworth metal itself. The molds are strengthened by steel hoops to resist this pressure. The pores and bubble-holes are thus effectually closed, and the compressed steel is given a strength and homogeneousness unequalled by any other known metal.

Fig. 222 shows how perfectly the process effects the object aimed at. Fig. 223 shows the appearance of the fracture of an unpressed ingot. The essential precaution to be observed is merely to get the metal under the press while quite fluid. This is sometimes found to present some difficulty. At Neuberg, where Bessemer metal is used, the process is stated to have given satisfaction. Compression thus does for steel castings, but even more effectually, what forging and rolling do in ordinary treatment.

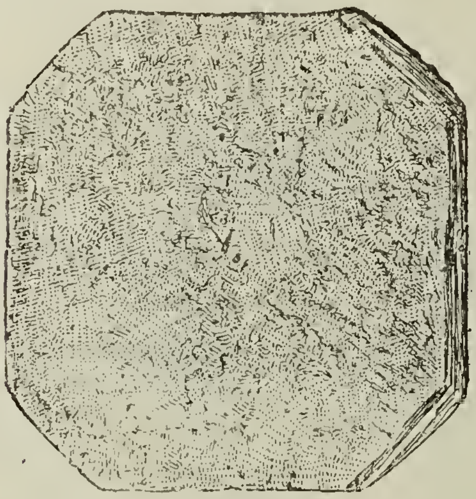

FIG. 222.

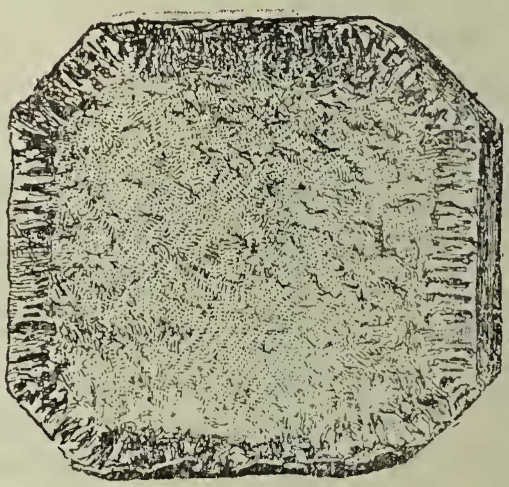

FIG. 223.

The inventor has stated to the writer that, by careful selection and treatment of metals, a steel can be produced capable of resisting a tensile stress of forty-five tons per square inch of section, and of elongating 25 per cent. before breaking. He furnishes the compressed steel in twelve grades, which he divides into groups, and distinguishes them by color-marks. The softest and most ductile is marked "No. 1, red," and the hardest is "No. 3, yellow."

The following is the classification:

No. 1, red, barrels for fowling-pieces, steam-boilers, &c.

No. 2, red, rifle-barrels, gun-carriages, &c.

No. 3, red, large guns, locomotive-cranks, &c.

No. 1, blue, lathe-mandrels, shafts, crank-pins, &c.

No. 2. blue, hydraulic presses, piston-rods, &c.

No. 3, blue, sword-blades, &c.

No. 1, brown, wire, coach-springs, hammers, &c.

No. 2, brown, cold-chisels, shears, boring-bars, smiths' punches, large taps, &c.

No. 3, brown, armor-shells, small drills, small taps, &c.

No. 1, yellow, screw-tools, dies for stocks, punches, &c.

No. 2, yellow, large drill, lathe tools, cutters, &c.

No. 3, yellow, extra hard, with least ductility.

No. 1, red, is a very strong, yet soft and ductile steel, which is particularly well adapted for small-arms. It withstands the sudden shock of quick-burning powder, and, as the projectile is of lead, is not scratched, as it would be in large ordnance. Heavy guns require a metal of great strength and toughness, but also hard enough to resist abrasion by cast-iron or steel shot and shell. Whitworth guns are made of No. 3, red. A harder quality (No. 3, brown) is used for shells intended to be used against armor-plate. The "red metal" has the advantage that, should the gun be burst, it would simply open like soft copper, and would not fly in pieces like cast iron or ordinary steel.

The hardness is determined, as in other steels, primarily by the proportion of carbon. The compactness and density, the soundness and homogeneousness, of this metal are its great advantages; its hardness and durability as compared with iron, the strength and toughness secured without forging, and its power of taking any desired form, without liability to those dangerous defects which accompany welding, are advantages which are of very great importance.

The Whitworth Company produces masses up to four tons weight, and it is not too much to expect that heavy ordnance may yet be made by this process in a single piece. The metal is tested for ordnance purposes in the following manner:

A hollow cylinder is made of the metal to be tested of 7.83 inches and 2.56 inches external and internal diameter, respectively, and 26 inches in length. The ends are closed by screw-plugs, which enter just far enough to leave an intermediate cavity of the capacity required by the cartridge of powder to be fired in it. A vent one-tenth of an inch in diameter is drilled through one of these plugs. The charge being fired, the cylinder must explode, or the gases must all rush out through this vent. A cast-iron cylinder was thus burst with one charge of 3 ounces of powder; another, having a wrought-iron lining, bore the shock of three charges of 5, 6, and 8 ounces, respectively, and exploded when fired with 10 ounces; a third cylinder, of Whitworth metal, was not even cracked after thirty-one trials, with charges of 1½ pounds weight each, and the enlargement of its interior diameter one-fifth and its exterior diameter one-twenty-fifth of an inch.

The elegant expedient of testing his ordnance by this method, with gradually-increasing charges, until an increase of internal diameter is detected, enables the maker to at once test the piece by an inexpensive series of trials, and to determine the maximum safe service charge—desiderata hitherto unattained, although of immense importance.

We have long since reached a limit in the manufacture of ordnance, of hydraulic machinery of some kinds, and, in especial cases, in mechanical engineering, beyond which we cannot go without using a new and stronger material.

The well-known fact that no thickness, however great, will enable a cylinder to resist an internal pressure per square inch greater than the tensile strength of the metal, limits the life of many kinds of constructions, and absolutely forbids improvement of others except by the use of stronger material. The introduction of such a new material is therefore one of the most important events in the history of engineering, and engineers look with exceptional interest upon all promising attempts in this direction.

416. GENERAL REMARKS on metal for ordnance and purposes demanding strength and resilience.

In selecting a material for ordnance, it is not sufficient that it should possess great strength, but it must be resilient; that is, it must, while offering great resistance to rupture, be capable of stretching considerably before breaking. Our best cast iron, for ordnance, has a strength of 37,000 pounds per square inch, and stretches usually less than one per cent.; wrought iron of good quality has a maximum tenacity of 60,000 pounds, and stretches twenty per cent.; bronze gun-metal resists 40,000 pounds, and stretches five or ten per cent.; good Bessemer and Siemens steel, containing one-third per cent. carbon, after having been worked by the rolls or under the hammer, usually have a tenacity of 70,000 pounds and a ductility of twenty or twenty-five per cent.; tool-steels are much stronger, but only stretch about two per cent. Whitworth states that his compressed steel *castings* have all the strength of, and greater ductility than, the worked steels of similar grade in carbon.

It is evident that even our remarkable American gun-iron, of which so much has been said, is among the very worst of all these available materials for ordnance. The fact that it has been used almost exclusively in this country is simply due to the inability of our manufacturers to supply guns of a stronger material without flaws due to welding in forged and to porosity in cast metal, promptly and at a price which our Government would pay. Wrought iron is much stronger, but its working into shape involves the formation of numerous welds, and consequently of points of weakness difficult of detection and liable at any time to produce disaster.

Low steels made by puddling or by the crucible, the Bessemer or the Siemens process, is a far better material, and the quality known as "homogeneous metal" is at once strong and tough; it can be melted and cast, or it may be forged. It is this metal which is made by Firth & Son for the inner tubes of Woolwich ordnance, and by Krupp for all parts of his ordnance. The castings must always, however, be forged sufficiently to close up all pores, or they will prove faulty and weak. The manufacture of large ordnance is, therefore, expensive, and requires great experience and skill.

The theoretical energy of gunpowder of fair quality is 250,000 to 300,000 foot-pounds per pound; its actual energy, as developed in ordnance practice, is from 150,000 to 200,000 foot-pounds. The initial velocity of the projectile, in heavy ordnance, may be taken as approximately

$$V=\sqrt{64.4\frac{E\,w}{W}}$$

in which formula V is the velocity in feet per second, E is the actual energy per pound of powder as determined by experiment, w is the weight of powder, W is the weight of projectile.

Cast-iron shot on striking armor-plate usually flies to pieces, and thus wastes about one-half the energy which it should expend in perforation;

wrought-iron or soft steel is deformed by compression, and thus loses probably one-fifth its *vis viva ;* hardened steel usually expends nearly all its energy usefully in penetration, but loses a little in elevation of its own temperature on impact ; where the latter splits longitudinally, as it sometimes does, it loses, perhaps, a tenth. To secure the best result, it is usually advisable that the shot should have a diameter nearly equal to the thickness of the armor-plate attacked ; it may sometimes prove effective when but one-half that diameter. Such slender shot demands the best of material. When steel is used, the writer has found the weight of charge, C, required for penetration to be about

$$C=\frac{t^3}{10}$$

or, the thickness *t* penetrable by a shot of correct proportions, driven by a given charge, C, is

$$t=\sqrt[3]{10\,C}$$

Cast-iron shot require the use of a double charge. British practice seems to indicate that where wrought iron is used for armor-plate, a tenacity of 50,000 pounds, a ductility of 20 per cent., a resistance to compression such that about 200,000 pounds per square inch of section will reduce small cubic specimens to one-half their original height, gives the best practical result yet attained, when backed with four times its own thickness of teak. With such plate, and flat-headed steel shot, if P is the pressure required to penetrate plate, U the work of the powder in foot-pounds, *t* the thickness of plate, and *r* the radius of the shot in inches,

$$P=255360\,r\,t$$

and for steel,

$$U=24400\,r\,t^2$$

and for cast iron,

$$U=10640\,r\,t^2.$$

A Woolwich 9-inch gun, of the Frazer-Armstrong pattern, penetrates 40 feet of earth, or 12 feet of brick or concrete, 8 feet of rubble masonry, 2 feet of granite, or 11 inches of iron with a charge of 43 pounds R. L. G. powder and a projectile weighing 270 pounds. The 600-pounder Woolwich gun with 70 powder, has driven a 600-pound shot through three 5-inch plates*, and has broken out the rear of a target composed of four 5-inch plates, penetrating the first three plates. The same gun has broken two solid 15-inch plates, one of which was rolled and the other hammered. At these experiments two 5-inch plates were found to be as strong as one 10-inch, and three 5-inch were stronger than one 15-inch plate. The difficulty of securing perfect soundness in the thicker plate more than compensates the defect of rigidity in the thinner. The Whitworth 9-inch, as has been seen, has done better work than the Woolwich ordnance. Our largest American ordnance of cast-iron cannot show such records as these.

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*Shoeburyness, June, 1868.

These experimental investigations and theoretical deductions, of national importance as they are, are of hardly less interest and importance in their bearing upon the arts of peace. For many applications in mechanical engineering, a material which is of value as a gun-metal is also essentially important, and the engineer in general practice watches the progress of improvement in ordnance with scarcely less interest than the engineer whose special work is the manufacture and use of ordnance. Both, also, are equally interested in attempts to introduce materials like cold-rolled iron, the softer steels, cold-rolled or "steel-bronze," phosphor-bronze and compressed steel, which give promise of aiding them in their efforts to produce machinery and structures more perfectly combining strength with lightness, or guns which are strong, reliable, and efficient. In all directions the progress of improvement is checked by the attainment of a limit set either by the weakness of the materials of construction or, oftener, by their deficiency in resilience.

The improvement effected by the processes just referred to would seem to be largely due to the production of that porosity which is the invariable characteristic of cast metals as ordinarily produced.

The experiments of the writer and the results of many tests of commercial materials in the Mechanical Laboratory of the Stevens Institute of Technology indicate that even with the best of ordnance bronze, as well as with the steels, defects of structure occur which must detract greatly from their value. It would seem probable that solidification under compression and other methods of securing density and homogeneousness may prove useful in many cases not yet thus treated.

417. SHEFFIELD.—The great steel and tool manufacturing establishments of Sheffield have long held a leading position, and one or two are probably ahead of their respective departments of business in Great Britain and the world. The United States, with large and more accessible deposits of rich ores, with ample capital, and the most skilful workmen to be obtained either at home or by importation, is gradually becoming perfectly independent of Great Britain in both the manufacture of steel and the making of steel instruments and tools. Our Besseme and Siemens steels are fully equal to any produced abroad. A number of our manufacturers produce tool-steels which are as strong and tough, harden as uniformly, and take as fine a temper as the best English metal, and the axes and some other descriptions of tools made in the United States are driving out English-made tools wherever competition occurs between them.* In many cases, where a special quality must be uni-

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*English edge-tool makers are fully aware of the success with which certain of their business rivals in America have supplanted them in many of our home and foreign markets. So large, however, is the demand at present for good edge-tools of almost every description that there are few edge-tool firms in the United Kingdom who have not plenty of orders upon their books. The English article is not, therefore, out of use, but there is a perceptible increase in the favor in which handy and thoroughly excellent tools are held, both at home and abroad; and this is being encouraged by the growing facilities for manipulating steel, both shear and cast. Sensible of this, formly worked and a precise temper is invariably demanded, the maker who has been brought up to the use of a certain make of steel, and with all his employés is thoroughly accustomed to its use, cannot safely give it up and attempt to substitute another steel with which he is less familiar, even though it be intrinsically better metal. This fact and the prejudice in favor of reputable makes of foreign steel retain an American market for English steels which would otherwise have been lost long since.

There remain, however, some Sheffield products which are not paralleled by anything in the United States, and we visited a few establishments partly to ascertain the character of their plans and of the methods which had yielded such excellent products as were exhibited at Vienna, and partly to see what might be found that was still novel.

Messrs. THOMAS FIRTH & SONS are the manufacturers of all the steel used for the inner tube of the Woolwich ordnance, and immense quantities are supplied for other uses. The metal is a soft steel, containing less than one-half per cent. carbon, and is made in crucibles. There seems no peculiarity in either material or method, and the secret of success would seem to be that the Messrs. Firth, by long experience in the selecting and working of their materials, can produce a steel very low in carbon of very uniform quality, and at moderate prices. Steel tested for the Midvale Steel Works and for Messrs. Miller, Barr & Parkin, by the Mechanical Laboratory of the Stevens Institute of Technology is of equally good quality, and the metal can be produced quite as well in the United States as in Great Britain. The Messrs. Firth have made large numbers of Enfield rifles and other arms for the government and for private contractors, and use the same metal in these small-arms. For heavy forgings, as for the tubes of heavy ordnance, a steam-hammer is used with a drop weighing 25 tons. The foundation on which the anvil block is carried is a single immense casting weighing 175 tons.

A considerable number of people are employed making files. The method has no novelty, and the excellent reputation of the Firth files,

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certain American firms are pushing their opportunity, and American forks, shovels and axes are to be had wherever edge-tools are offered in this country. It would seem that the Americans believe they can compete with us much more successfully by having branch establishments to manufacture their specialties in this country rather than by shipping their produce from the other side. A firm of cast-steel shovel makers at Pittsburgh, (Messrs. Hussey, Binns & Co.,) who have recently brought out a shovel in which the straps, though of iron, are compacted with the steel during the process of casting, and who are making, at a very low figure, and with very little manual labor, shovels that are getting very rapidly into use throughout the States, are now, through a representative who has recently come over from Pittsburgh to England, making inquiries which will regulate their action and determine them whether they will themselves begin to make in this country, or whether they will offer their process to English firms or to an English company. If American edge-tool makers should begin to produce here goods that are already running English makers hard, then it is to be inferred that their example will be followed by other transatlantic hardware manufacturers. Whether in such an event the English firms would remain as well employed as they now are remains to be seen.—*London Times's Wolverhampton Correspondence.*

like that of their gun-steel, is due to conscientious attention to detail and to selection of materials. The number of workmen employed here varies from 1,000 to 1,500.

After a luncheon with the gentlemen of the firm whose hospitality and courtesy we are bound to acknowledge, we visited the great rolling-mills of their neighbors.

Sir JOHN BROWN & Co. have one of the largest establishments in Sheffield, or in Great Britain. They employ about 6,000 men, and produce from 2,500 to 3,000 tons of finished material every week. This product is principally steel, in the form of rails and tires. This firm and Messrs. CAMMELL & Co., who have also an immense establishment close at hand, have heavy armor-plate mills, in which nearly all of the armor of the British fleet has been rolled. The first of these plates which were but 4 inches thick, were rolled at the Park Gate Iron-Works, in the West Riding of Yorkshire. The next heavier plates were 4½ inches thick, of hammered iron, and were made by the Thames Iron-Works. Messrs. JOHN BROWN & Co. now have the heaviest rolls in the kingdom, and at our visit they were put in operation, and we were able to see the process of rolling. The rolls were reversed at each pass by the use of a heavy clutch. The heavy plates are built up of thinner plates, which are rolled separately. The rolls are about 32 inches in diameter and 8 feet long. There are two sets, the second of which has rolls 30 inches in diameter.

A considerable amount of Bessemer and large quantities of crucible steel are made here. The crucibles used are made at the works. Railroad-car springs are made in great numbers and of exceptionally fine quality. Neither here nor elsewhere in Sheffield did we perceive any radical departure from ordinary methods. The reputation of Sheffield manufacturers and the excellence of their exhibits at Vienna seems to be due simply to care and skill in selecting materials, care and skill in working them, and care and skill in inspection and preparation of the products for the market, and a conscientious adherence to the schedule of qualities placed in the hands of their customers. A spirit of emulation is encouraged in the workmen, and in some of these establishments the workmen are as much interested in the preservation of a reputation for good work as are their employers.

418. SOUTH WALES.—In South Wales, although there is less to interest or instruct the visitor than in some of the manufacturing districts already referred to, there is still something to be seen.

Near Merthyr Tydvil are the great Dowlais Iron-Works, founded by Sir John Guest, and now employing in its mines and its mills about 12,000 people, and producing annually about 30,000 tons of steel rails and large quantities of iron. The management of these mills has exhibited an exceptionally enterprising spirit, and a promising novelty, whether of mechanism or method, is seldom refused a trial here by Mr. Menelaus, the manager. The steel made here is principally produced by the Bessemer process. The mills lately put down are reversing mills fitted with well-designed Ramsbottom reversing engines. The laboratory of the Dowlais Works is one of the most complete in Great Britain, and it has not only done good routine work, but the accomplished chemist, Mr. Snelus, has produced some really scientific work.

The ores worked for the Bessemer process are lean native ores, containing about 45 per cent. oxide mixed with a large dose of either rich Cumberland or the excellent Bilbao ores, which, until the occurrence of political troubles in Spain, seemed likely to compete with the former with some success. For common irons, the native ores, which contain a considerable amount of phosphorus, are principally used. Welsh rails are therefore not perfectly safe in very cold climates. The following analyses represent the constitution of good Welsh ores and iron:

Ore of South Wales:

Protoxide of iron	40. 30
Protoxide of manganese	1. 03
Alumina	1. 43
Lime	1. 44
Magnesia	2. 77
Carbonic acid	28. 33
Phosphoric acid	0. 88
Sulphuric acid	Trace.
Bisulphate of iron	0. 09
Water	0. 78
Organic matter	0. 29
Insoluble residium	22. 48

Cast iron of South Wales:

Carbon	2. 95
Silica	1. 96
Sulphur	0. 28
Phosphorus	0. 68
Manganese	0. 23
Nickel and cobalt	0. 04

419. THE SIEMENS STEEL PROCESS.—A few miles from Swansea, the seat of the copper-smelting industry of South Wales, is the little village of Landore, where the now well-known Siemens process of steel-making was perfected.

The process has often been described, and its peculiarities and advantages have already been stated incidentally in preceding portions of this report. There is, therefore, but little that need find a place here. At Landore it has become a commercial success. It was introduced into continental establishments previous to the date of the Paris Exposition of 1867, and was imported into the United States by Messrs. Cooper, Hewitt & Co. The able report of Mr. Abram Hewitt, which is embodied in the reports of the United States Commissioners to the Paris Exposition, contains nearly all information relating to it which would be valuable to either the engineer or the metallurgist. It is still worked at Landore with perfect success, and the visitor finds there specimens as fine in quality as any exhibited at Vienna. The modified process, called by Mr. Siemens the ore process, in which ore is used in large doses as a decarbonizer, is still passing through its experimental stages, and, as the distinguished metallurgist who has so long and persistently labored upon the problem believes, with promises of ultimate success. There are serious difficulties to be overcome in the attempt to reduce the ores and to make steel on the hearth. The most serious is that of finding a material of which to make the bed not liable to be fluxed by the ore and to cut through so rapidly as to make the delay and expense incident to its repair a serious addition to the account of costs. The subject is one of importance to the metallurgist and of great interest to the engineer.

The regular Siemens process, as carried out at Landore, is similar to that already described. Pig-metal is melted on the hearth of the regenerative furnace, under a decarbonizing flame, and is completely decarbonized by the oxidizing flame, and by the addition of wrought scraps, which assist as a diluent. It is supposed that the carbon is also partly removed by the peculiar phenomenon of "dissociation," which is known to occur in other cases in which compounds which are stable at ordinary temperatures, are exposed to intense heat. When the charge is thorthoroughly decorbonized, it is retained under a neutral flame until—the desired degree of recarburation being given by addition of *spiegeleisen*—it is found, by the examination of small test ingots, to be of the right quality, when it is tapped off and treated as in Bessemer steel manufacture. The economical value of the process will be determined to a great degree by the value of scrap-metal. In some states of the market it is probably more profitable than the Bessemer process. Skill and care are required for its successful working; but skill and care can produce a finer and more uniform quality of product in this than in the other process. For the manufacture of "steels," or more properly irons, containing less than 0.3 or 0.4 per cent. carbon, this is probably the only satisfactory and reliable method of production. It allows of the use of light grades of cast iron; it permits the addition of any "medicine" required to eliminate deleterious elements; it permits the thorough and deliberate examination of the product and its modification to suit requirements before it is tapped off; it requires comparatively inexpensive plant, can be carried on in small establishments, and can be adopted in any locality, experimentally, without very great expense or risk. Now that manufacturers of machinery are beginning to see that for many purposes the soft, ductile, but strong and homogeneous metal, produced by this process, is of peculiar value for much of their work, it is to be expected that its adoption will rapidly take place.

420. J. PENN & SONS.—While in London the opportunity was taken to visit the establishment of Messrs. John Penn & Sons, at Greenwich.

This is one of the oldest in Great Britain and in Europe. The engine-factory is at Greenwich and the boiler-works at Deptford, a neighboring village. The works are large, and are well provided with tools. The buildings are irregularly distributed over some ten acres of ground. Those recently erected are well built, large, well lighted and ventilated, and provided with all the modern tools and conveniences. The machine-shops are in both old and new structures, the latter of which are well arranged, and contain the erecting shops with their powerful traveling cranes. These buildings are 250 feet long and 200 feet wide. The roof is carried over in four spans, and provided with windows, through which the shops are principally lighted. Each section is provided with a traveling crane. There are many fine tools here, and among them some of original design and exceptional efficiency. Among the latter is a vertical planer, in which the cross-head traverses and the work remains stationary. In these shops were several small driving-engines which attracted attention by their resemblance in design to what American engineers are accustomed to call the Oliver Evans engine—an engine which was used in the United States in 1784—and by the fact that they were not provided with such an expansion apparatus as is, by us, considered essential. In the foundery we found some of the smoothest and soundest castings which we had seen in Europe, quite equal to the beautiful cylinder casting exhibited at Vienna by the Creusot Company. Carefully selected iron and molding sand, skillful workmanship, and good judgment in parting and gating the molds give sound castings, and care in venting and in washing and blackening gives this remarkable smoothness.

We found in the erecting shops several very large engines, among which were two pairs of marine-engines of 1,150 and 1,200 "nominal" horse-power, equal to about 6,500 and 7,000 indicated horse-power, respectively. These were trunk-engines, a form which has been built successfully by Penn & Sons, but by no other firm, for many years. For merchant steamers they were building the Napier style of compound engines. There is less steel used here in construction than in other establishments which have already been described; but this firm are unusually conservative, and rarely risk either capital or reputation on experiment or novelties. They have been among the very last to adopt the compound engine. They have no large hammers, and obtain their heaviest forgings from Liverpool and Glasgow.

Messrs. Penn & Sons are also building some oscillating engines, a type to which they have adhered, in building paddle-engines, for many years, and with great success. Their success, both with this and with the trunk-engines, is attributed by many engineers not to the merits of these peculiar types of engines, but to the excellence of proportion and the superiority of workmanship which has always distinguished the machinery built by this firm. Neither of these kinds of marine-engines is generally approved by engineers.

In going down the Thames, *en route* to Greenwich, we saw very little ship-building going on in yards which a few years ago were crowded with work. Samuda's yard contained several vessels, and at a few other places a ship was now and then seen hauled up for repairs. Iron-ship-building will probably never again flourish on the Thames. The river itself needs a "Clyde Trust" to preserve its depth of channel and to keep its banks in proper shape.

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SEWING-MACHINES.

G. A. FAIRFIELD.

VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON

SEWING-MACHINES.

BY

GEORGE A. FAIRFIELD, ESQ.

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CHAPTER I.

SEWING-MACHINES AT VIENNA.

American Compared with European Machines; Description of European Machines; Description of American Machines; Conclusions.

1. Comparison of American with foreign machines.—Although the sewing-machine department was one of the largest in the International Exhibition of 1873, it was found, as in that held in Paris in 1867, that it belonged pre-eminently to America, and that nearly all of the great variety of machines exhibited were either American in their construction or in their design, or were with few exceptions copies, more or less faithful, of well-known American machines. We may say without egotism that, however meager our display in many other departments, America has done herself credit in this, and her inventors and manufacturers have fully sustained their high reputation as occupying the front rank in the construction of practical labor-saving machinery.

It is not the purpose of the writer, nor is it necessary at this late day, in reviewing the present condition of the art, to go even so far back as 1844, when the first rude American sewing-machine was struggling into practical being.

A grateful public has long since acknowledged its obligations to those early inventors, and it is especially gratifying to note that neither extended research nor the accumulated products of the world's workshops can change the well-established fact that to American genius belongs the credit of constructing the first practical machine devoted to that purpose.

But while America may justly claim to have been the pioneer in this great branch of industry, it must be admitted that other nations have not been backward in utilizing her productions; so that to-day the sewing-machine is recognized as a household necessity throughout the civilized world, and its manufacture, as the large display at Vienna attests, is no longer confined to the United States.

Although we have exported no less than one million sewing-machines during the past ten years, this vast number has not been sufficient to meet the growing demand; and as a result we find scores of manufactories, of greater or less extent, springing up throughout Great Britain and the Continent, employing thousands of workmen and producing hundreds of thousands of machines annually. They seem to find a ready market at remunerative prices, as each year adds largely to the list of competitors; but notwithstanding this great accumulation of capital and skill, European-made machines are admitted to be inferior to those of American manufacture, and command a lower price in the open market. This may be explained by the following facts:

First. It is desirable to combine strength with grace and delicacy of construction in a family sewing-machine. In this we have the advantage, as the metal from which the frame-work of our machine is made is much finer and stronger, and will admit of more delicate formation.

Secondly. Most of the small or moving parts of the machine are made in duplicate by automatic machinery, and consequently are interchangeable and easily replaced when worn or broken.

Thirdly. For a similar reason that Italy is admitted to be the home of art in sculpture, America may be considered the home of fine labor-saving machinery.

2. EUROPEAN SEWING-MACHINES.—Among the fifty different exhibitors of sewing-machines at the Exhibition at Vienna, Germany led all other nations in the number of small manufacturers and dealers, there being not less than twenty-nine distinct makers represented, all of whom may be briefly noticed in this report:

(1) Messrs. POLLACK & SCHMIDT, Hamburg, exhibited machines of their own manufacture, on the Wheeler & Wilson system; also hand-machines, single-thread, on the Willcox & Gibbs system. They also presented a new tucking-attachment.

(2) Messrs. NECKAR & CO., Berlin, exhibited a new glove stitching machine of some merit, quite original in design.

(3) Messrs. PEERS & CO., Hamburg, exhibited machines designed expressly for tailors' use, both hand and foot; shuttle driven by horizontal shaft in the arc of a circle. They have novel points of some merit.

(4) E. PRUCKNER, Berlin, exhibited a variety of machines, mostly built on the Singer system, and very good copies. This is an old and reliable house.

(5) Messrs. LANGE & LINDNER, Berlin, exhibited machines made on the Singer system. Nothing new, and poor copies.

(6) Messrs. LUDU, LOEWE & CO., Berlin, exhibited machines very like the Weed, No. 2; also machines built on the Howe system, with new vibrating presser-foot; also new embroidering-attachment. This firm are extensive manufacturers of other machinery, mainly copies of American designs.

(7) Messrs. W. BREMER & CO., Braunschweig, exhibited both hand and foot machines on the Howe system, with Domestic shuttle-movement.

(8) Messrs. THEODORE ORTH & CO., Leipzig, exhibited machines on the Singer system adapted to leather-work. Not new.

(9) Messrs. BASSERMANN & MONDT, Mannheim, exhibited a combination of the Singer and Schofield movement; shuttle driven by horizontal rocking shaft. Has some good points.

(10) W. H. KERNAUL, Berlin, exhibited machines of Wheeler & Wilson system, with new needle-plate; also a new device for fastening cloth-plate; also a new feed and stitch regulator. All good.

(11) A. CONRAD, Leipzig, exhibited a very heavy-geared machine on the Singer system. Quite old.

(12) C. HOFFMAN, Leipzig, exhibited heavy machines for working in leather—a combination of the Singer and Howe systems. An old and reliable house.

(13) Messrs. GRIMME, NATALIS & CO., Braunschweig, exhibited machines made after a combination of the Howe and Domestic systems. They also presented a knitting-machine.

(14) CHN. MANSFELD, Leipzig, exhibited a fine machine adapted to leather-work, with Singer needle-movement, raised shuttle-race, working in arc of circle, driven by segment of a gear. They also build machines on the Howe and Manning systems.

(15) Messrs. DÜRKOPP & SCHMIDT, Bielafeld, exhibited machines quite similar to English designs. This is a very enterprising house.

(16) THE UNION SEWING-MACHINE COMPANY, Hamburg, Th. H. Menke, manager, exhibited heavy machines made on the Howe system, with large shuttle and compensating thread-controller, to admit of passage of shuttle through the loop. This is one of the best machines of German manufacture.

(17) HEINRICH SCHATZ, Weingarten, exhibited embroidering-machine, with swinging arm, universal movement, and hook-stitch.

(18) CARL GEIGER, Stuttgart, exhibited copies of all the standard American and English machines. He is an extensive dealer.

(19) ROBERT KIEHLE, Leipzig, exhibited copies of the Weed manufacturing-machine, Broaderick system. Works well.

(20) Messrs. BRAWS & LUDWIG, Chemnitz, exhibited a cylinder or arm machine; chain-stitch. Not good.

(21) Messrs. SEIDEL & HAUMANN, Dresden, exhibited machines of the Wheeler & Wilson and Singer systems. This is quite an enterprising firm.

(22) AUGUST HENSEL, Bayreuth, exhibited copies of the Weed manufacturing-machine, Broaderick movement. Not new.

(23) Messrs. JUNKER & RUH, Carlsruhe, Baden, exhibited machines with Howe needle-system and Domestic shuttle-movement. Combination quite new and good

(24) Messrs. BAER & REMPLE, Bielafeld, exhibited machines of the Wheeler & Wilson system.

(25) Messrs. J. BALLIN & CO., Hamburg, exhibited machines made on the Wheeler & Wilson, Singer, and Empire systems.

(26) The BREMEN SEWING-MACHINE COMPANY, Bremen, exhibited Kallmeyer's patent button-hole machines; also Howe-system machines.

(27) RICHARD SCHMIDT, Hamburg, exhibited the Victoria machines, both hand and foot.

(28) Messrs. LANGSDORFF & MAYER, Hamburg, exhibited machines made on the Wheeler & Wilson and Willcox & Gibbs systems. They also show a French machine, with oscillating shuttle—a good combination.

(29) ROBERT LÖSCHE, Dresden, exhibited machines made on the Howe system; also a combination of the Schofield and Singer systems.

The following are from other parts of the Continent:

(30) H. P. HENRICKSON, Copenhagen, exhibited some fine glove-machines.

(31) H. DEMANT, Odense, exhibited a great variety of machines made on the Wheeler & Wilson and Singer systems, both hand and foot; also good glove-machines, cylinder and open bed or arm machines, like the Howe and Manning styles.

(32) A. NEILSON, Aarhuus, Denmark, exhibited hand-machines of Willcox & Gibbs and Wanzer systems.

(33) C. KONERDINGS, Copenhagen, exhibited machines on the Singer system, and one adapted to glove-stitching.

(34) N. NARHOLM, Copenhagen, exhibited glove-machines only.

(35) Messrs. BERGMANN & HUTTERMEIER, Copenhagen, exhibited good glove-machines.

(36) Messrs. HURTU & HAUTIN, Paris, exhibited heavy wax-thread machines, with awl in advance of needle for piercing the goods, followed by needle with thread which forms the stitch. They also show a light-top feed-machine with rotary shuttle and extension bed. A good house.

(37) E. CORNELY, Paris, exhibited Bonnaz embroidery-machine, with universal feed and stop-motion attachment.

(38) THIMONNIER'S MACHINE.—In passing through the French section in the machinery-hall, the writer's attention was called to a very antiquated piece of machinery, which, upon a closer inspection, appeared to possess the crude ideas of a sewing-machine; and standing there upon its three legs, it seemed in its crippled condition, bent with age and gray with the dust of fifty years, to ask only of the busy throng that brushed rudely by, or stopped to admire some one of its numerous offspring, that they would but respect its age and learn something of its early history. This old veteran contains all the elements of our modern sewing-machine, except the feeding-mechanism. It was invented and made as early as 1825 by B. Thimonnier, who obtained a patent for it in France in 1829. The fourth machine, constructed in 1848 by this inventor, was exhibited in London in 1851, and in Paris in 1855, where it was awarded a medal of the first class.

B. Thimonnier was born in L'Arbresle, department of the Rhone, on the 9th of August, 1793, and died August 5, 1857, at Amplepuis.

The machine here exhibited was presented to the Academy of Industrial Arts and Sciences of Lyons by the sons of the inventor. It is a rude piece of workmanship, made mostly of wood, and it requires a vivid imagination to discover in it anything of the sewing-machine of the present. It has a pedal which, when pressed upon by the foot, brings down a croçhet-needle—a movement similar to the portable mortising-machinery so common throughout this country. It is a single-thread, chain-stitch machine, and seems to have no distinct feeding-device. The spool is held underneath the machine; the needle catches the thread, draws it up, and forms the stitch, leaving the chain on top.

This instrument is worthy of some thought, not so much for what it is as a mechanical triumph as for its being the outcome of one of the earliest authenticated efforts of the human mind to invent that device, which at the present day is a necessity in every household.

(39) Messrs. LOUIS BOLLMANN & Co., Vienna, exhibited machines built on the Wheeler & Wilson, Grover & Baker, and Howe systems; all copies. They made a creditable display.

(40) G. FERSTL, Vienna, exhibited copies of Singer machines.

(41) Messrs. VIDAL & ENGLER, Vienna, exhibited glove-machines, very good for overcasting stitch, using a hook and horizontal needle-bar.

(42) AUGUST RAST, Vienna, exhibited machines on the Grover & Baker system. He manufactures largely for the trade.

(43) Messrs. PAPP & SASNA, Vienna, exhibited copies of the Howe and Wheeler & Wilson machines.

(44) JOSEPH SCHREIBER, Vienna, exhibited machines of the Wheeler & Wilson system. He also produces the Grover & Baker chain-stitch on the Wheeler & Wilson machine. He presented a new and practicable tucker.

(45) Messrs. KLAWATSCHEK & KONIG, Vienna, exhibited copies of the Wheeler & Wilson and the Ætna machines, with some improvements in the shuttle.

(46) JOSEPH KOPPITZ, Vienna, exhibited copies of the Wheeler & Wilson machine; also a machine with revolving needle-shaft, cam in head, and rocking shuttle-movement.

(47) V. REICHL & Co., Vienna, exhibited copies of the Grover & Baker and Singer machines.

Of English machines there were but four presented:

(48) Messrs. BRADBURY & Co., Oldham, exhibited a machine called the "Practical Tailor," which is quite new and original in construction. One new feature in this machine is that it has three rotating shafts extending from front to rear, which impart direct, positive motion to the needle, shuttle, and feed. These shafts are all yoked together, and driven by means of one link and three disks, held in position by projecting pins and corresponding steps to receive them. They also have a double feeding-mechanism, taking hold both sides of the goods. This machine is quite original, and does good work.

(49) Messrs. NUSSEY & PILLING, Leeds, exhibited a variety of machinery, including the Tudor lock-stitch machine for tailors' use; also a small hand-machine called the "Little Stranger." Their display was good.

(50) P. B. TAYLOR, London and New York, exhibited a new and novel hand-machine which is wonderfully simple. Its moving parts may be counted on one's fingers. It does its work rapidly and well.

(51) W. TURNER, Birmingham, exhibited the Thomas machine, which is favorably known as a leather-machine; also cylinder and hand machines. They had a fine display.

Canada was represented by—

(52) R. M. WANZER, Hamilton, Ontario, exhibited the Little Wanzer in a variety of styles, both hand and foot. This has been a very popular machine throughout Europe, and has even found its way into Asia. It has intelligent energy behind it, as its elaborate catalogue, published in twenty different languages, fully attests.

3. AMERICAN SEWING-MACHINES.—We now come to the American department, and although there were really but eight of the many American makers represented, it was around those richly-furnished and well-filled stands that the public invariably lingered. There the votaries of this cunning art always found something new to interest them, and it was there that a final struggle for supremacy culminated. There could be found there, set in a handsome frame-work of lace, tapestry, and gold, all that was beautiful and practical, both in the sewing-machine and in its products. It was there that some of the most powerful corporations of America vied with each other, and finally united in one common effort to sustain the high reputation our country has gained in former exhibitions for her mechanical skill, as shown in the construction of all kinds of intricate and delicate machinery.

(53) THE HOWE MACHINE COMPANY, Bridgeport, Conn.—As one entered the United States section, on his right he found perpetuated the name and well-earned fame of him who gave his best days to devising and perfecting that justly popular machine which bears the title of Elias Howe, jr.; and so well was his work done that time has suggested but few minor changes in its construction. This machine is especially fitted for leather-work, for which the following points show its advantages:

First. It is so constructed that both upper and under threads draw together, thus finishing each stitch as the goods pass under the presser-foot.

Secondly. It has a very sensitive shuttle-tension, which is indispensable on fine work.

Thirdly. The head containing the needle-bar is adjustable—a very fine point in this machine. As it has been so often described, it is unnecessary to do more than call attention to the following figures:

Fig. 1 represents the machine complete, thrown back, showing the under side, with all the driving-mechanism presented to view. Number 10 on this figure shows the bed-plate rubber, attached to the bed; Number 11 is the table-rubber in its position; 13 is the small driving-pulley on the main shaft; 144, large driving-wheel in position on the stand; 239 indicates the hinge inserted in the rubber socket attached to the table, as seen at number 241.

Fig. 1.

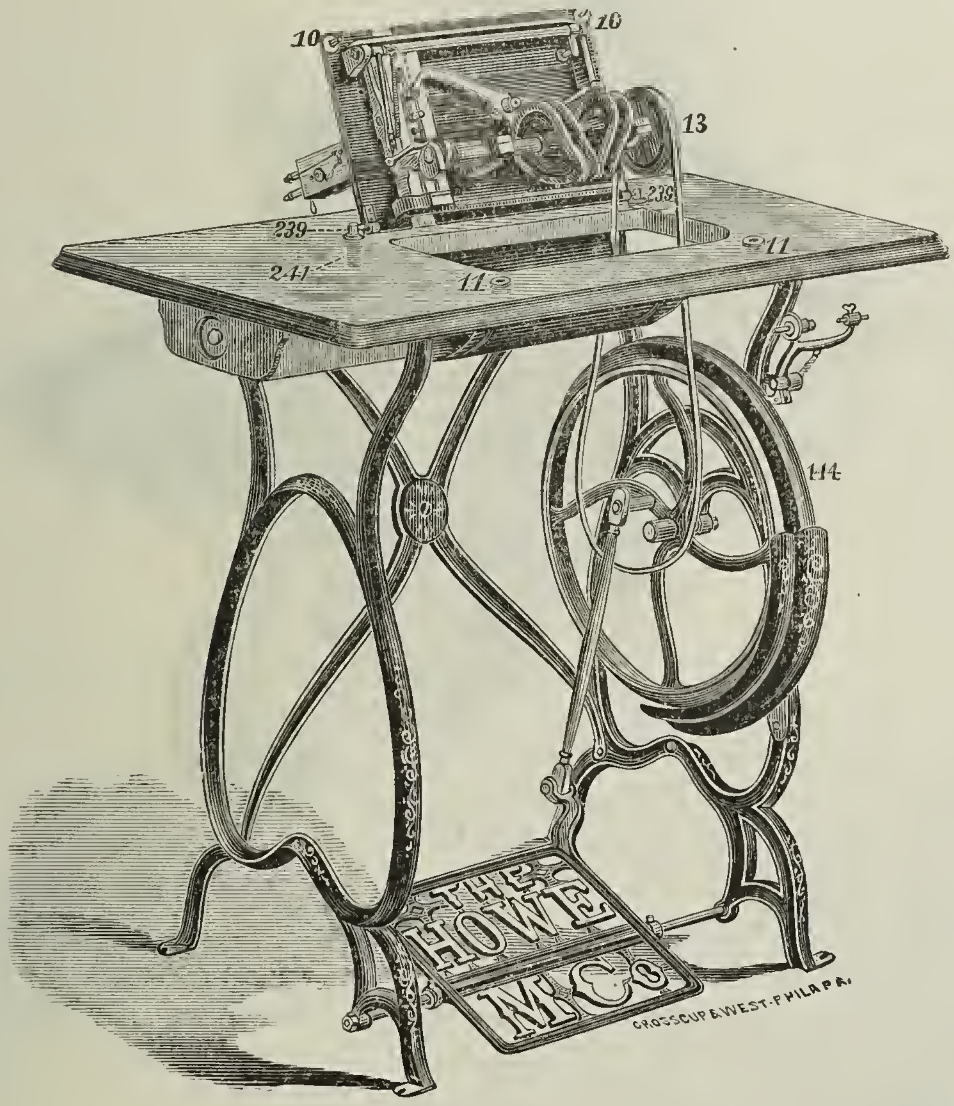


Fig. 2 gives a general view of the machine detached from the stand. Number 1 on this cut indicates the stitch-regulating bar; 2, the main back journal; 3, the needle-driving cam; 4, the shuttle-driving cam; 5, the main front journal; 6, the cam for raising the feed; 7, the cam for driving the feed; 8, the feed-lever; 9, the feed-lever attached to the feed-bar; 10, the shuttle-driver slide in position; 11, the shuttle-driver link; 12, the same attached to the shuttle-driver arm; 13, the stitch-regulating adjustment; 14, the bed; 15, the thread-controller; 16, the presser-bar; 17, the needle-bar; 18, the needle-bar piston in position; 19, the needle-lever stud in position; 20, the shuttle-lever stud in position; 21, the shuttle-lever; 237, a part of hinge attached to the bed;

239, the part of the hinge that enters the table; and 240, the pin connecting the same.

Fig. 2.

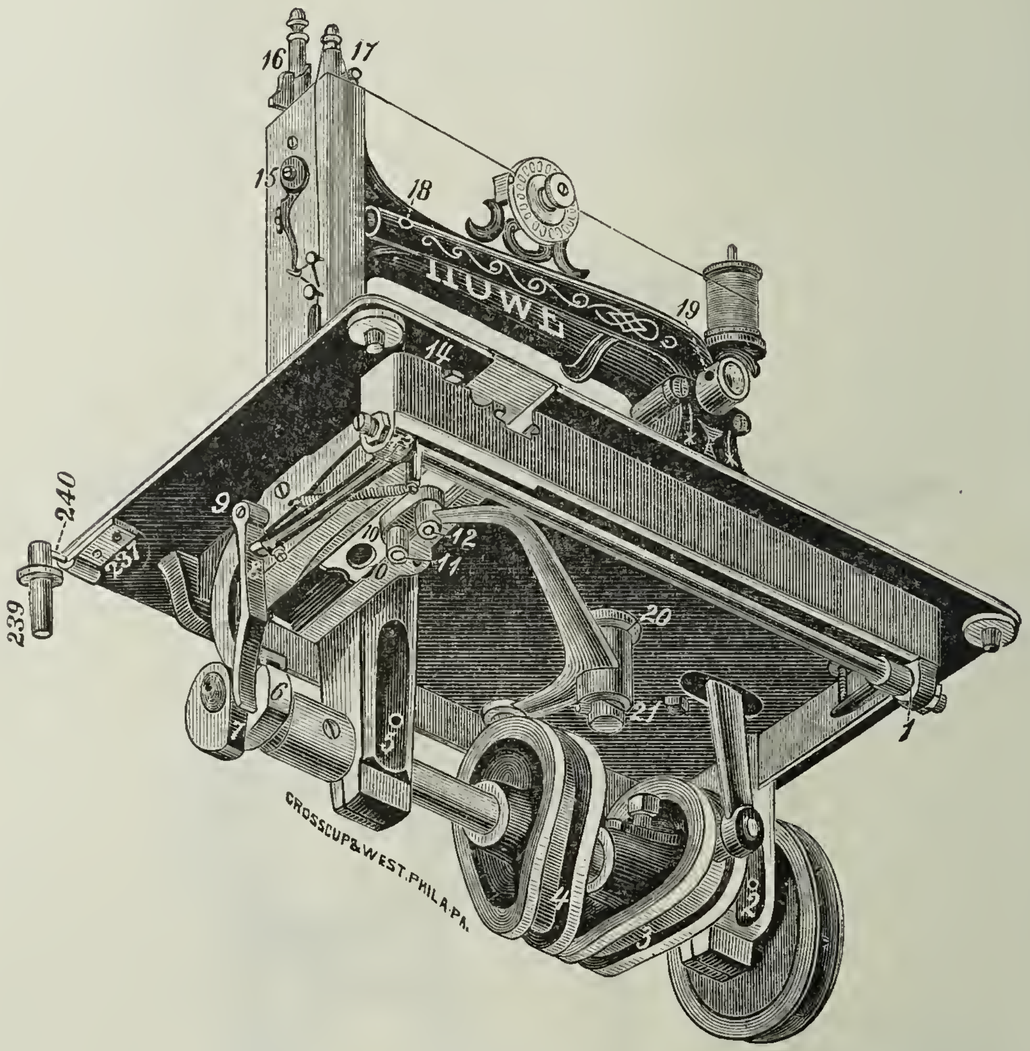


Fig. 3.

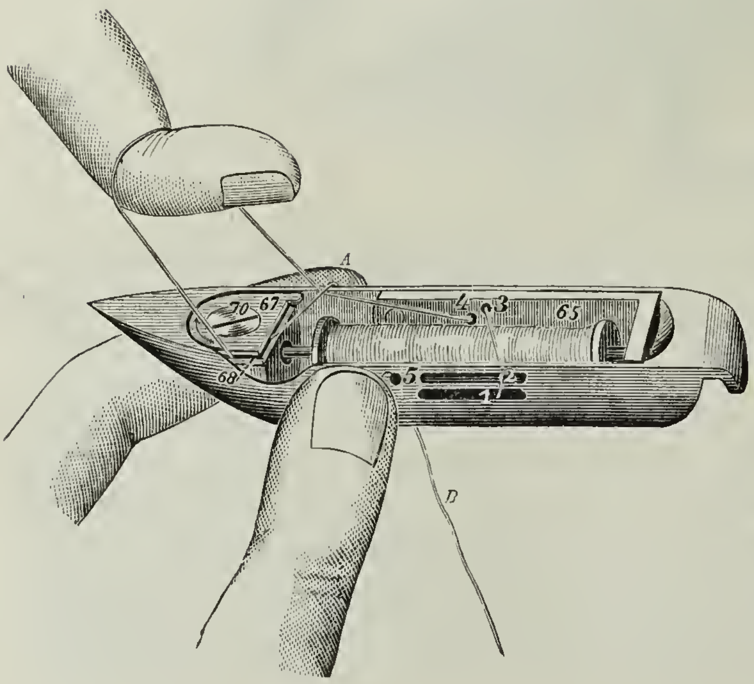
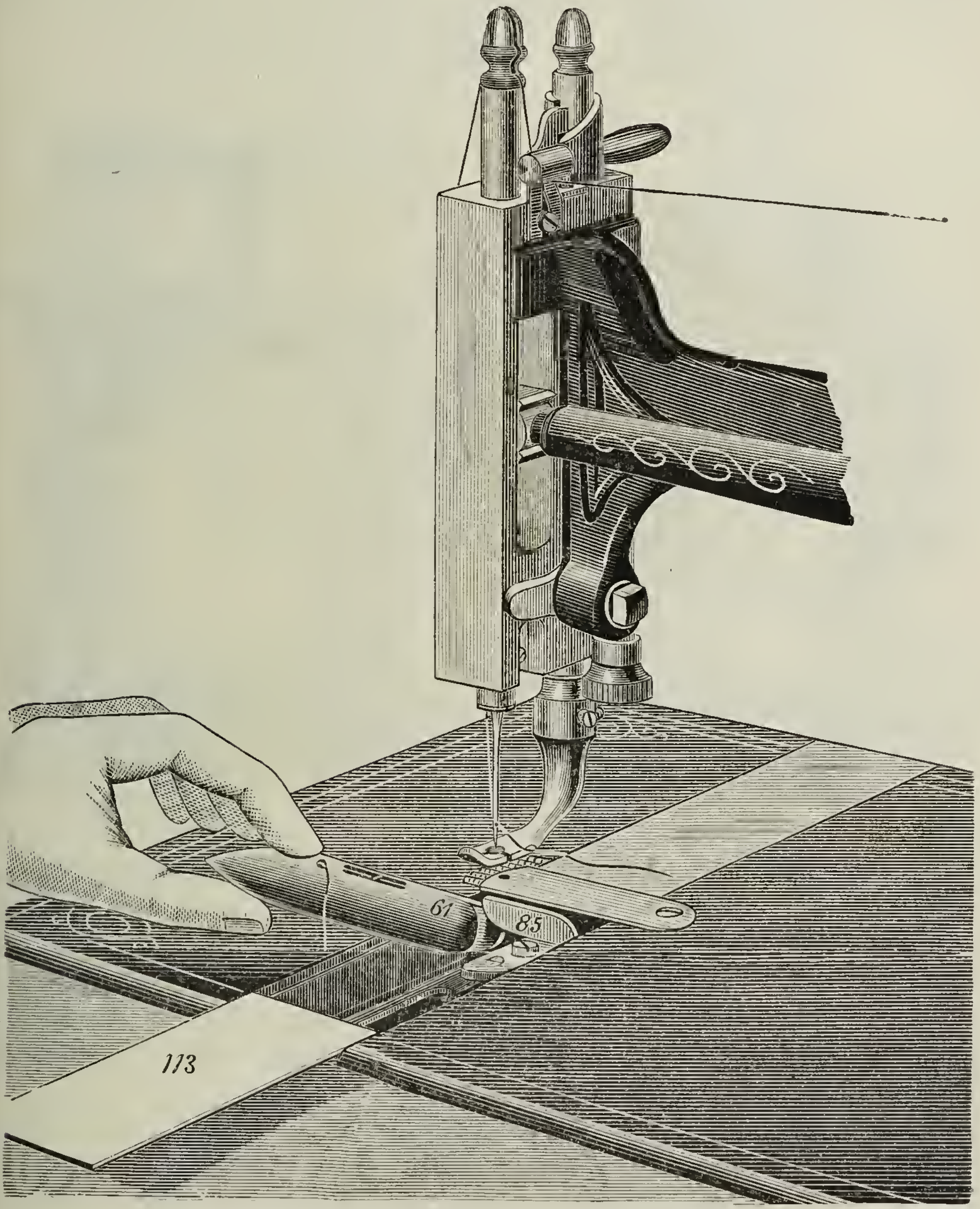


Fig. 3 is a cut showing the form of the shuttle and the method of threading it. Numbers 1 and 2 indicate the thread-distributing slots; 3 and 4, the position of the thread in the latch; 65, the latch which holds the bobbin in position; 67, the upper tension-plate; 68, the position of thread under the tension-plate; A, the passage of the thread around the distributing-bar or latch; and B, the thread as drawn out ready for sewing.

Fig. 4 is a view of a section of the machine, showing the needle and presser bars and the position of the shuttle. Number 64 on this cut shows the shuttle entering the race; 85, the shuttle-driver; 113, the front slide-plate removed to admit the shuttle into the race.

Fig. 4.



(54) THE WILLCOX & GIBBS SEWING-MACHINE COMPANY, New York.—Close beside this sturdy old pioneer, and dancing "like a thing of life" to music that can hardly be heard, was that paragon, in its charming simplicity, of all single-thread machines—the Willcox & Gibbs. This machine, small and quiet as it is, has pushed its way into all quarters of the globe. It is extremely simple in its construction and perfect in its workmanship, and, as a result, it runs with ease. Being free from fric-

tion, it will admit of a high rate of speed, and is very durable. Although it belongs to that class known as single-thread or loop-stitch machines, it does its work so uniformly well that it is deservedly popular for many kinds of fine work. Perhaps its strongest point is found in the ease with which it runs.

The two following figures (5 and 6) show the styles of these machines:

Fig. 5.

No. 1.

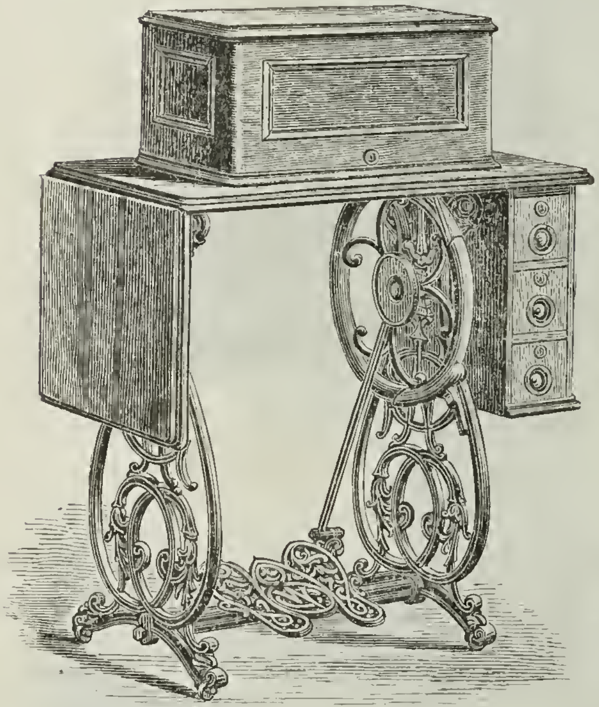
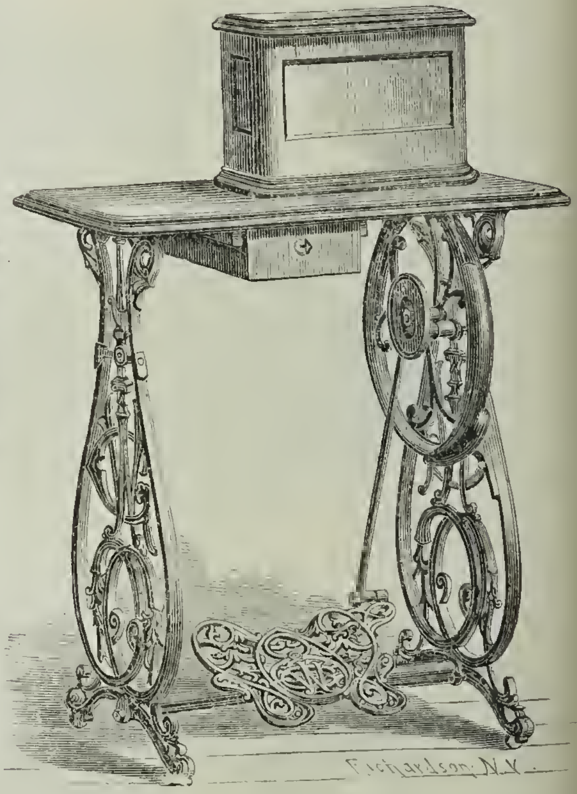


Fig. 6.

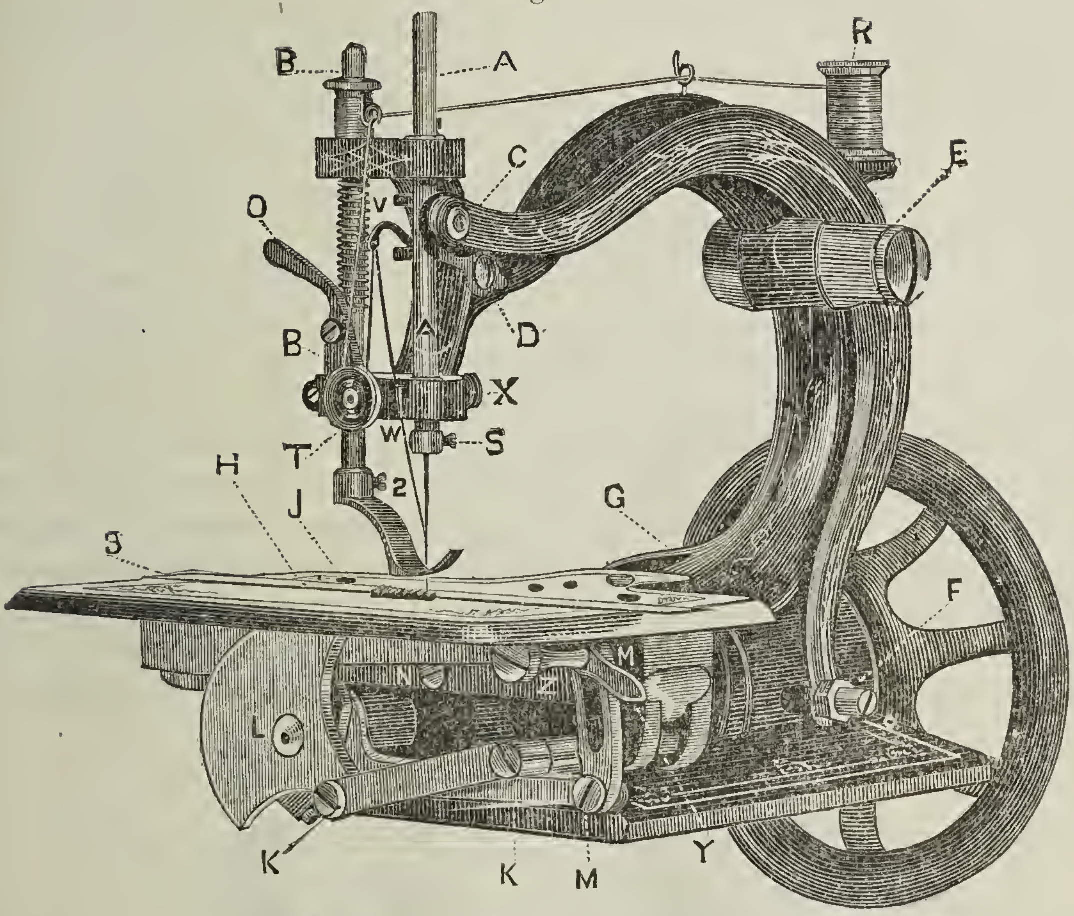
No. 2.


Richardson N.Y.

(55) The Secor Sewing-Machine Company, Bridgeport, Conn.—Just opposite, on the left, was exhibited a comparatively new machine, known as the Secor. It is gracefully formed and well made, embodies many of the best-established principles which insure durability and speed, and runs easily. With all its advantages it should become popular, especially when it is known that it is manufactured in the sewing-machine city of Bridgeport.

Figure 7 (on page 15) shows the complete mechanism of this machine: Letter A indicates the needle-bar; B, the presser-bar; letter C, the needle-bar connecting-screw; D, the take-up joint; E, the needle-arm screw; F, the cam-slide and stud; G, the rear journal of main shaft; H, the front journal of main shaft; J, the oil-cup on shuttle; KK, the shuttle-driver pitman; L, the crank and feed-movement; MM, the feed-link; N, throat tube-screw; O, the presser-bar lifter; R, the spindle for spool; S, the needle-gripe screw; T, the tension-disks; V, the eye-end of the check-lever; W, the thread-guide next to needle; X, the tension thumb-screw; Z, the feed-connecting-bar thumb-screw to lengthen or shorten the stitch.

Fig. 7.

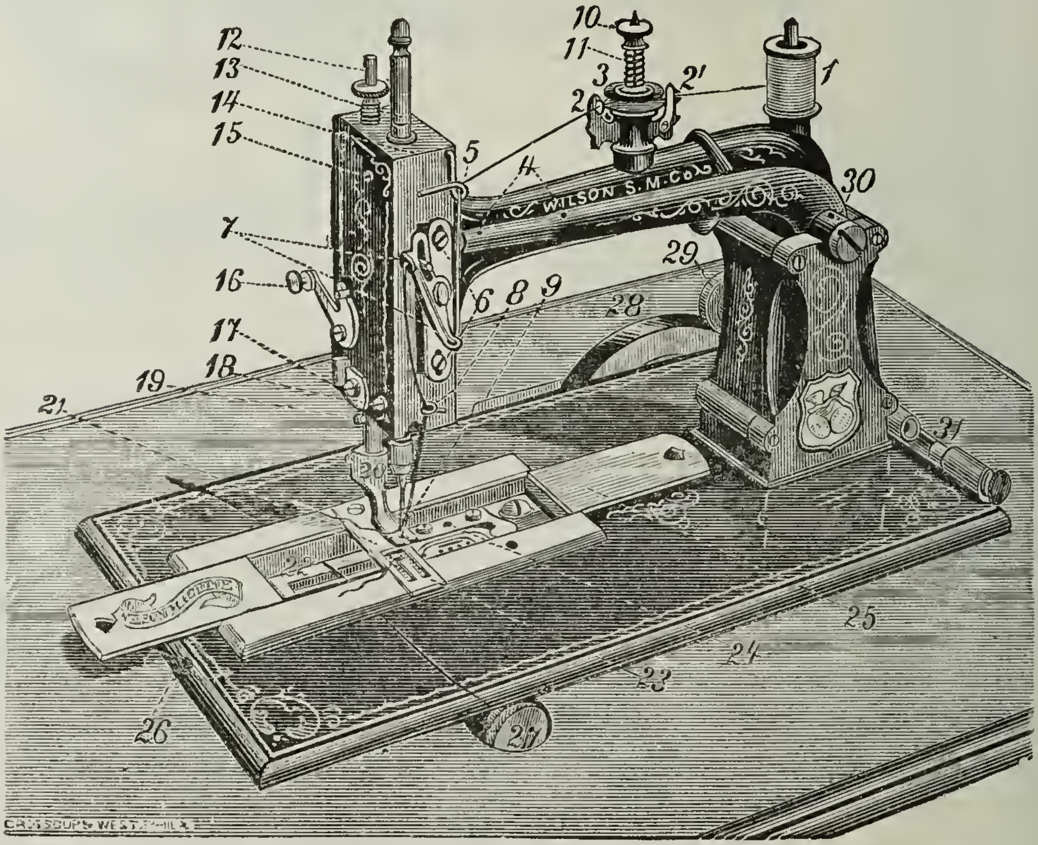


IMPROVED SECOR SEWING-MACHINE.

(56) The Wilson Sewing-Machine Company, Cleveland, Ohio.—A little further on the attention of the public was attracted by a beautiful female figure, elegantly attired like some Parisian princess, and the visitor was astonished to discover that the exquisite garments were not painfully wrought by the hands of scores of French costumers, but that it was the counterfeit presentment of a Buckeye maiden clad in what might, under the circumstances, be justly called her homespun. It was all produced with perfect ease on one of the many Wilson machines which surrounded it. This instrument does a great range of work, as it indicated by the samples shown. It runs, with great precision, from the most delicate gauze to the heaviest leather. It has a new combination of crank and cam, and has a transverse independent shuttle-race, which insures an open, square, lock-stitch, without undue friction on the thread. It also has the advantage of a long shuttle-driver or pitman—a good point, as it avoids sharp angles. It has a short, straight needle and a steel shuttle. The samples shown were splendid specimens of workmanship. Its great popularity fully attests the skill and energy of the man whose name it bears.

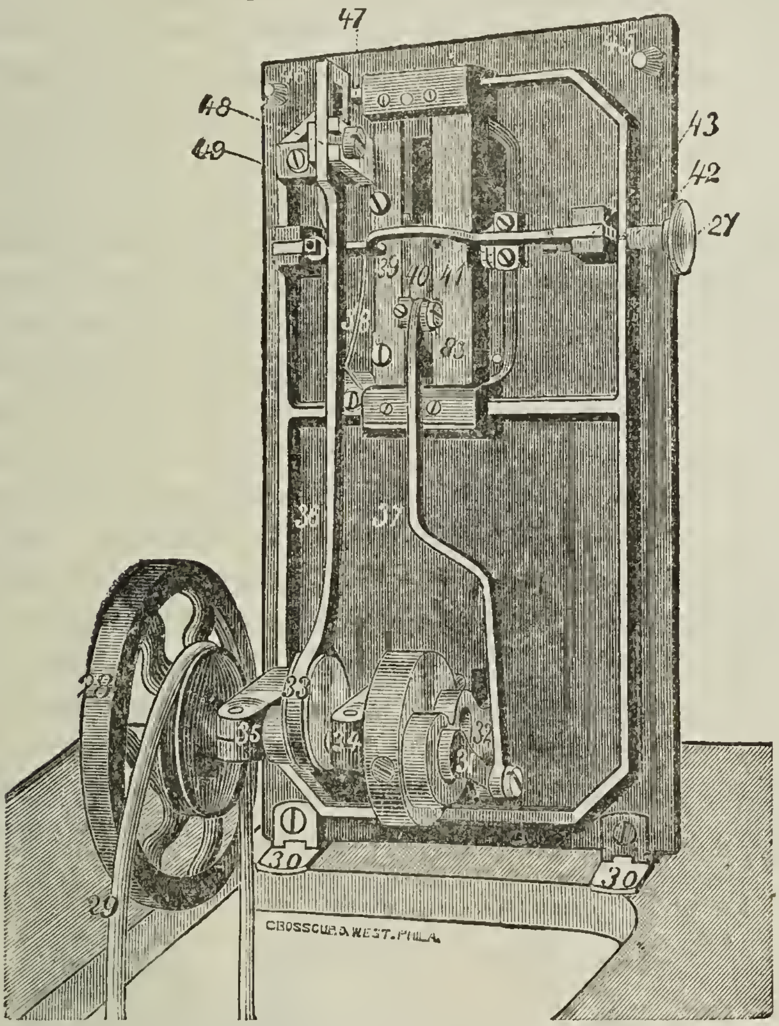
In the engraving (Fig. 8) all of the essential pieces and parts of the Wilson sewing-machine are illustrated. At 1 is the spool-holder; 2 and 2^1, thread-guides in the tension. Thread-guide 2^1, at the right of the tension, also represents the tension-check spring; 3 is the tension-wheel; 4 indicates oil-hole; 5 is a thread-guide; 6 indicates the screws that hold the take-up on the family machines to the face or head of the machines, and which by loosening permits the take-up being adjusted to different extremes of thick or thin fabrics. At 7 are thread-guides in take-up ; 8 is a thread-guide; 9 indicates the eye of the needle; 10 is the tension-nut; 11 is the tension-spring; 12 indicates the presser-foot bar, and 13 the presser-bar thumb-screw. At 14 there is a bushing or thimble in the head of the machine, called a needle-bar bushing; at 15 and 18 are set-screws to tighten these needle-bar bushings; at 16 is the presser-bar lifter; 17 represents an adjustable slide and set-screw for keeping the presser-foot tight and firm; 19 indicates the set-screw for holding the quilter and braid-holder; at 20 the presser-foot is shown; 21 indicates the throat-plate; 22 the shuttle-race; 23 the feed; 24 the shuttle-driver; 25 the right shuttle-race slide, and the left slide is described by having stamped on it "Wilson Machine." At 26 a hole is indicated in the bed of the machine; this hole is used exclusively for shipping purposes; 27 represents the feed-screw; 28 the balance or fly wheel on the machine; 29 the rubber ring on the bobbin-winder wheel; 30 is an oil-hole; 31 the bobbin-winder spindle, and indicates the place to put in the bobbin.

Fig. 8.—The Wilson Machine.



The under side (Fig. 9) of the Wilson sewing-machine, like the upper side, is very simple in its parts. At 30 and 39 the hinges are illustrated; 29 shows the leather belt; 34 and 35 indicate take-up screws for keeping the driving-shaft always snug and tight; 31 is the shuttle-connection crank, and 37 is the shuttle-connection; 32 is the heart-cam; 36 is the feed-connection; 28 again shows the balance or fly wheel on the machine; 38 is the feed-spring; 40 is the shuttle-driver slide; 41 and 83 is the shuttle-race; 39 is an adjustable part of the shuttle-race, and

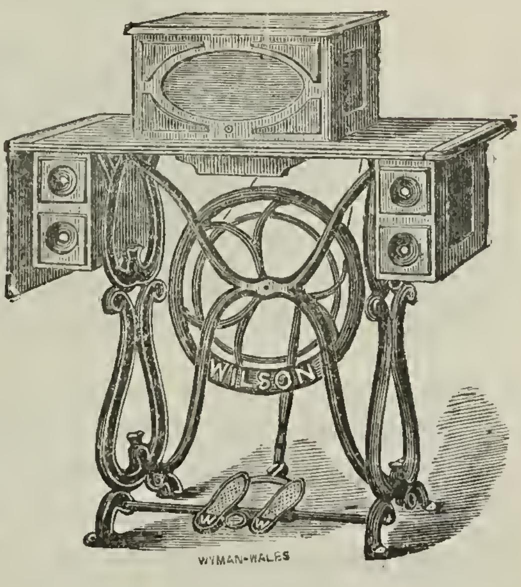
Fig. 9.—The under side.



CROSSCUP & WEST. PHILA.

is secured to the race by the screw in either end of it, which may be loosened, when the slide can be moved to the right, which will "tighten up" the shuttle-driver slide; 43 is the feed-bar; 42 is the feed-screw spring, and is used to prevent the feed-screw from getting loose and varying the length of the stitch; 27 again represents the feed-screw; 45 and 46 represent two projections on the bed of the machine which drop into the holes in the table-rubbers; 48 is an angle-iron, to which the fulcrum-screw in the feed-connection is attached; 49 is a box or bushing in the slot of the feed-connection, and 47 is the fulcrum-screw in the feed-connection. This screw, if moved down, will raise the feed and by moving it up it lowers the feed.

Fig. 10.



WYMAN-WALES

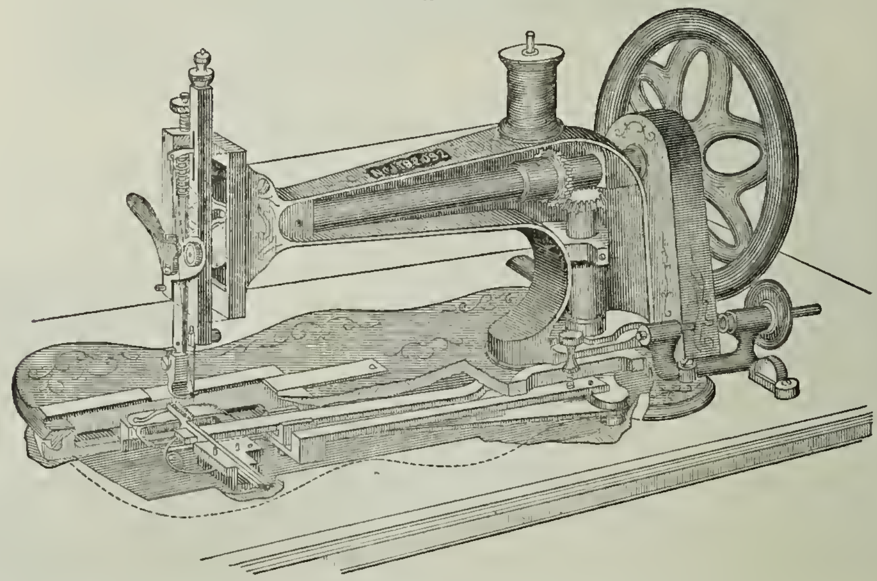
Fig. 10 is a view of one of the Wilson family machines mounted on drop-leaf, half-case table, ready for work.

(57) WEED SEWING-MACHINE COMPANY, Hartford, Conn.—A few steps further on was the stand occupied by this company. It was small and plainly furnished, and well stocked with a variety of machines, all in plain dress and ready for business. None were considered too good for practical work, but they were all called upon to speak for themselves, and were exact samples of the regular goods as furnished to the trade.

The " F. F.," or " Family Favorite," requires no introduction. Their new "G. F." is designed for manufacturing purposes, with a new and effectual stop-motion attachment, which is of great utility in rapid sewing, such as this class of machines is called upon to do. It enables the operator to stop the working parts at will by simply pressing upon a knob which projects through the bed, thereby disconnecting the mechanism of the machine from the driving-pulley, allowing that to go on without interruption or loss of speed. At the same time the presser-foot is lifted from the goods, releasing the work and allowing it to be turned at will. Always stopping with the shuttle in the loop, no stitches are dropped. Removing the pressure from the knob, the machine starts instantly at full speed. This is one of the really new improvements seen at the Exhibition; and that it possesses great merit is beyond a doubt.

One of the machines manufactured by this company under a number of patents granted to George A. Fairfield is shown in Fig. 11.

Fig. 11.



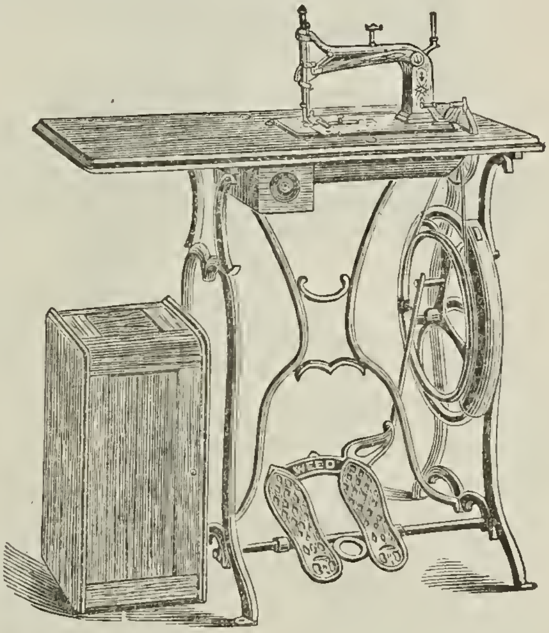
The main shaft is provided with an eccentric, and by means of a link is connected with an arm of a rock-shaft, supported in the over-hanging arm of the machine, and the rock-shaft has, at its forward end, a second ram connected by a link with the needle-bar; and in this way the needle-bar is reciprocated.

The needle-thread is controlled by a take-up lever carried by the needle-bar, and connected with a link to cause it to so move as to take up and to cause slack thread, as the movements of the needle and shuttle require.

The shaft has a second eccentric connected by a link with a short rock-shaft, provided with a slotted arm, which moves the feed-bar, which is of the usual four-motioned class, and on shaft *a* is also a crank connected by a link with a shuttle-carrier, the rotation of the crank reciprocating the shuttle across the machine under the cloth-plate. A part of the cloth-plate and head are shown as broken away to illustrate the construction of the parts.

The cuts illustrating the family machine made by the Weed Company, and the cuts illustrating the Singer Company family machine, are kindly furnished by Messrs. J. B. Ford & Co., New York, publishers of Knight's Mechanical Dictionary, edited by Edward H. Knight, esq. One number of Knight's Mechanical Dictionary will be devoted entirely to sewing-machines, and will contain a list of sewing-machine patents issued in this country, which will prove of great interest to all who are interested in sewing-machines.

Fig. 12.



The following figures represent the different styles of these machines:

Fig. 12 is a view of the machine mounted on plain half-case stand or table.

Fig. 13.

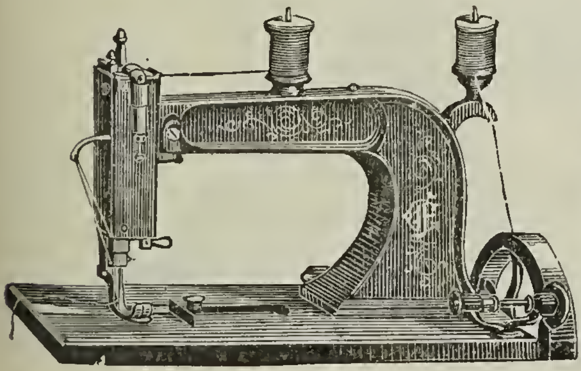


Fig. 14.

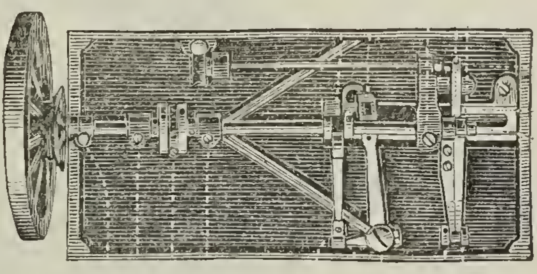


Fig. 13 is a view of plain "G. F." machine, threaded, ready for use.

Fig. 14 is a view of the under side of the machine, showing its working principles.

Fig. 15 is a top view of the "G. F." stop-motion machine, with the fingers of the operator pressed on the knob which disconnects the driving-mechanism.

Fig. 16 is a section showing the under side of this machine, with the lever that operates the stop-motion.

Fig. 15.

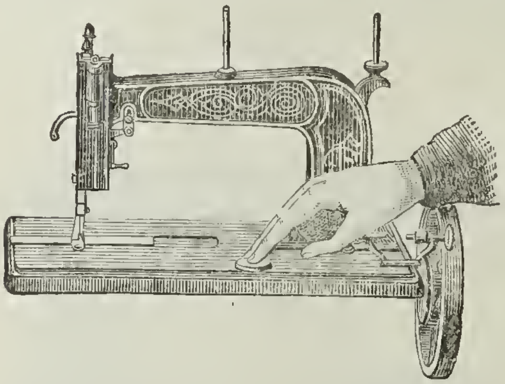
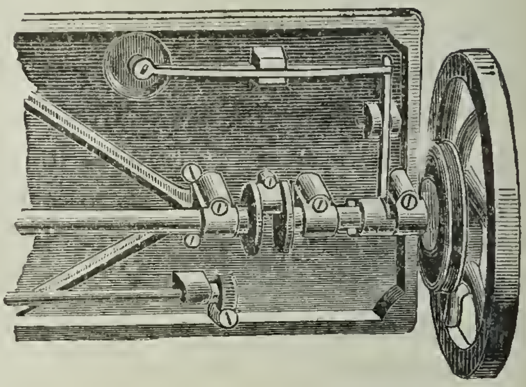


Fig. 16.



(58) SINGER MANUFACTURING COMPANY, New York.—The next in line was the mammoth pavilion of the Singer Company, gotten up on the liberal scale distinguishing everything connected with this establishment. Large as it was, it was filled with a splendid assortment of their standard machines, embracing samples of each of the great variety of machines manufactured by this the largest of all the sewing-machine companies.

To describe specimens of what these machines, with their attachments, could produce would require more time than can be given to them in this report. This great pavilion had the look of a vast workshop in holiday attire. There was nothing particularly new shown by this company, as they have recently made but few changes; and yet their machines are so well known and popular that the amount of their production and sales largely exceeds that of any of the other companies. This is one of the oldest and best-known machines in the market, and its reputation is not confined to this or any other country, but is universal, it being a familiar machine the world over, and one which has stood the criticism of time wonderfully well.

Fig. 17.

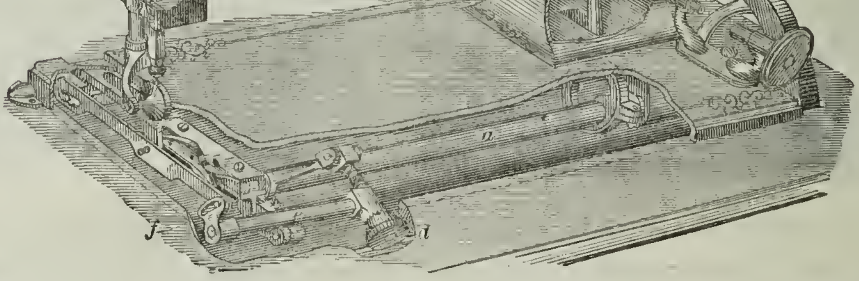


Fig. 18.

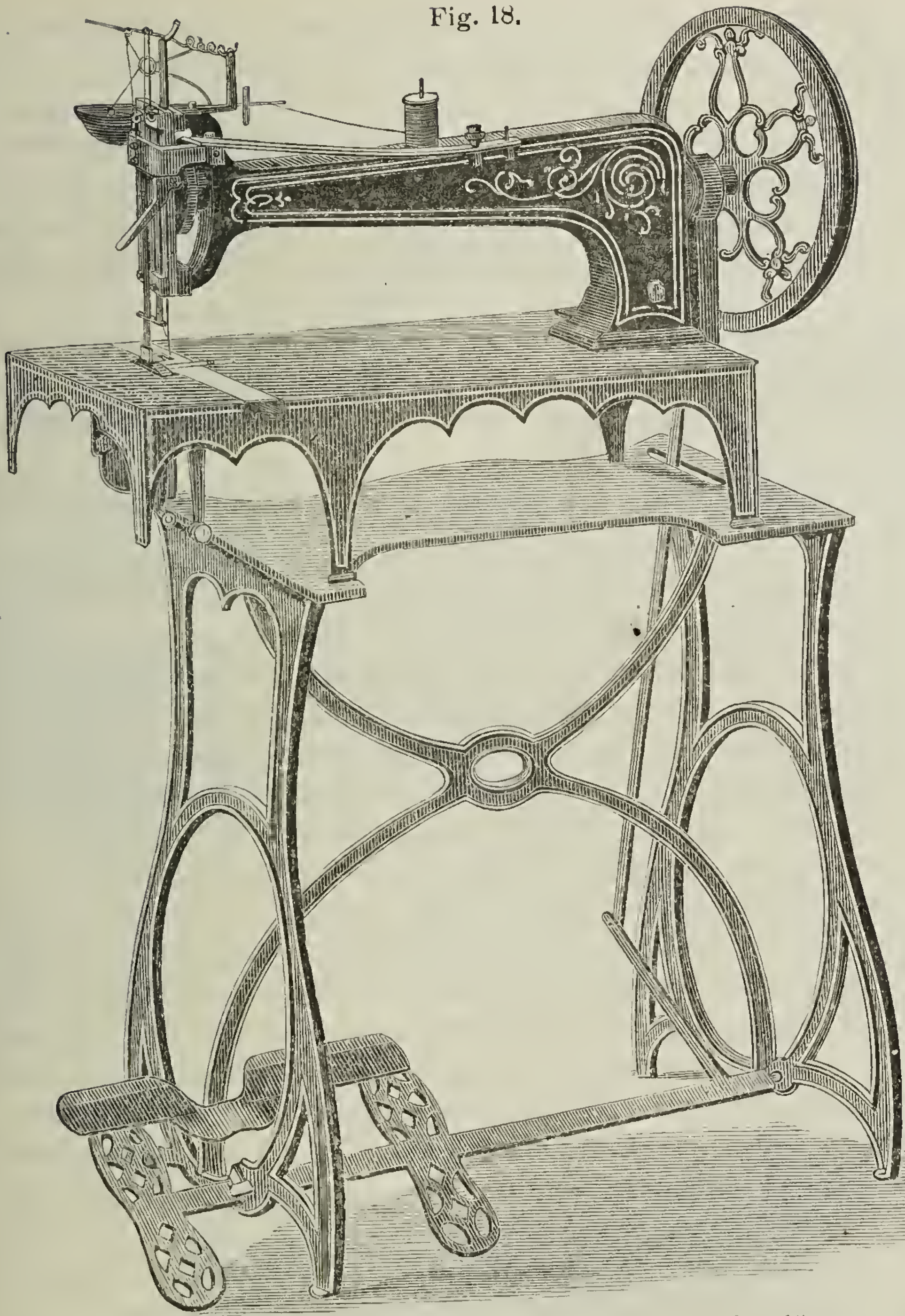
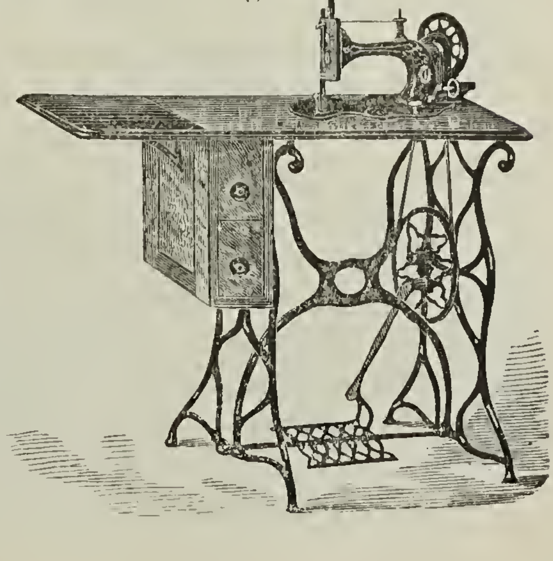


Fig. 19.



The main shaft of the Singer machine, as represented in Fig. 17, has a crank, with a pin, which enters a slot in a heart-shaped cam, connected with and operating the needle-bar, provided with an eye-pointed needle, the shape of the cam being such as to give the needle the proper fast and slow motions, to form and open a loop of needle-thread and draw up the stitch. On the main shaft is a bevel gear meshing into a second bevel gear on the upper end of a vertical shaft, provided below the cloth-plate with a crank and cams for operating the four-motioned feed and the shuttle, which is reciprocated by a shuttle-carrier, moving in a horizontal plane in the direction of the length of the cloth-plate. The length of the feed is regulated by a small screw, shown as working in a slot at the right of the figure, the cloth-plate at that part being broken away, and the face-plate of the head being taken off, to show the construction of the operative parts.

The movements of these machines are recognized as good, and are copied by scores of makers.

Herewith are presented also two complete views of these machines.

Fig. 18 is a view of the manufacturing-machine, mounted, and ready for work.

Fig. 19 is a view of the family machine, also ready for the operator.

(59) THE WHEELER & WILSON MANUFACTURING COMPANY, Bridgeport and New York.—On the opposite side of the aisle, pleasantly located, was the saloon occupied by this company. Everything connected with it was in perfectly good taste; its ceilings draped with silk and velvet, and its supporting-columns gracefully arched, and shaded with the choicest lace and damask. Here the visitor trod on the softest velvet carpets, all the surroundings being in perfect keeping with the fine display of machines and samples. This company may truly claim to have been one of the pioneers in this branch of industry, and Allen B. Wilson, the inventor of this quiet-running, rotary-hook, family sewing-machine, is recognized the world over as one of the few original inventors in this department; and large numbers of makers, not only in America, but in Europe also, are only too glad to avail themselves of the well-tried principles found in this machine. This is proven by the large number of copies exhibited. The family machine requires no introduction or explanation.

They also exhibited a new manufacturing machine, called No. 6, differing materially from the family machine in many respects.

The accompanying figures will enable the reader to judge of the style and movements of this machine.

Fig. 20 is a complete view of the machine ready for use, with thread in position. Numbers 1 1 1 show the bed, with its projections; 3, the needle-bar; 6, the arm-post; 8, the presser-bar; 10, the spool-pin, with spool in position; 11, the driving-pulley; 17, the needle-arm; 24, the oil-cup; 28, the presser-bar spring; 29, the presser-bar lifter; 31, the needle-plate; 33, the front slide-plate; 34, the ring-slide; 36, the stitch-regulator; 53, the presser-bar-spring screw; 55, the cloth-plate; 58, the take-up-lever pivot; 63, the ring-slide screw; 67, the thread-jack wire; and 71, the take-up.

Fig. 20.

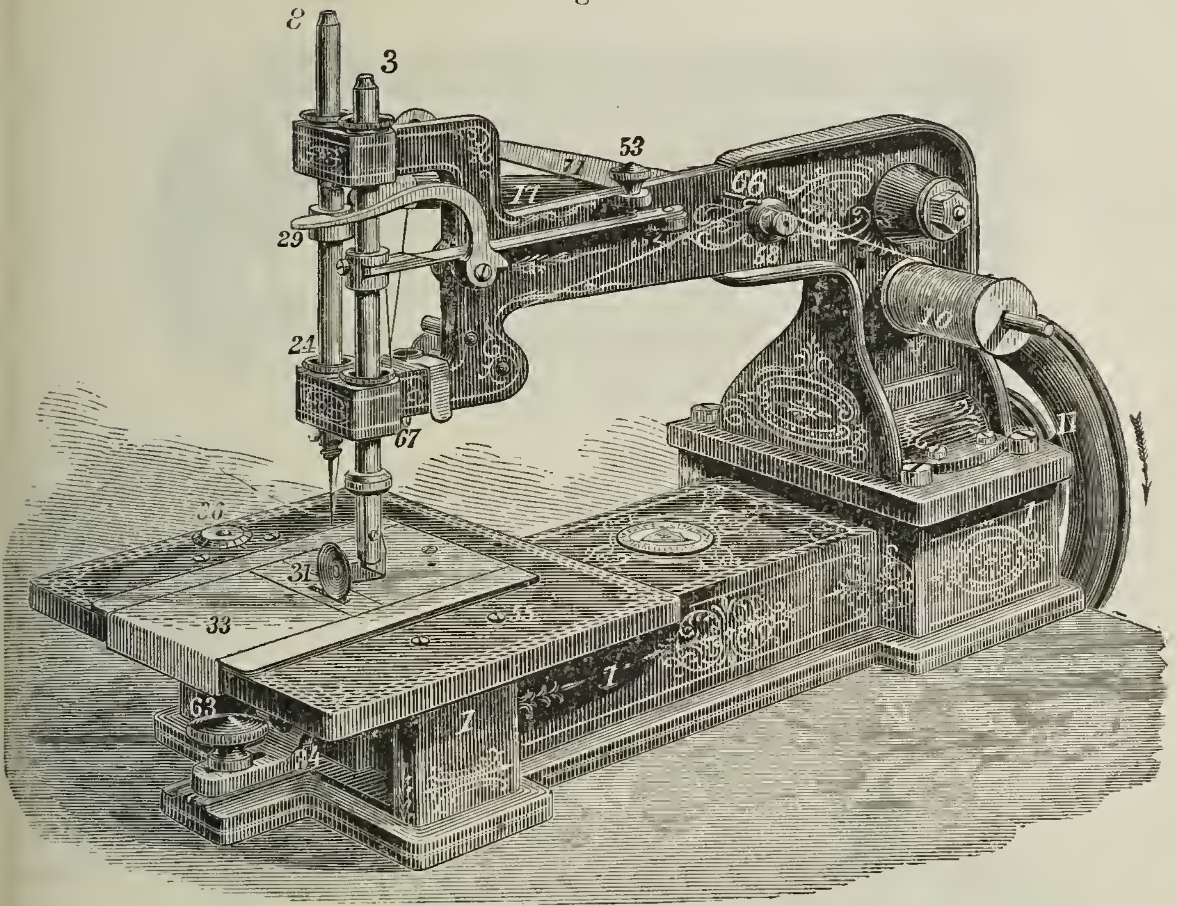


Fig. 21 is a view of the machine with the cloth-plate removed, showing position of hooks, number 19, feed-bar 7, and hook-yoke 80. It also shows the upper tension at 75, the rotating hook at 19, and the presser-foot at 31.

Fig. 21.

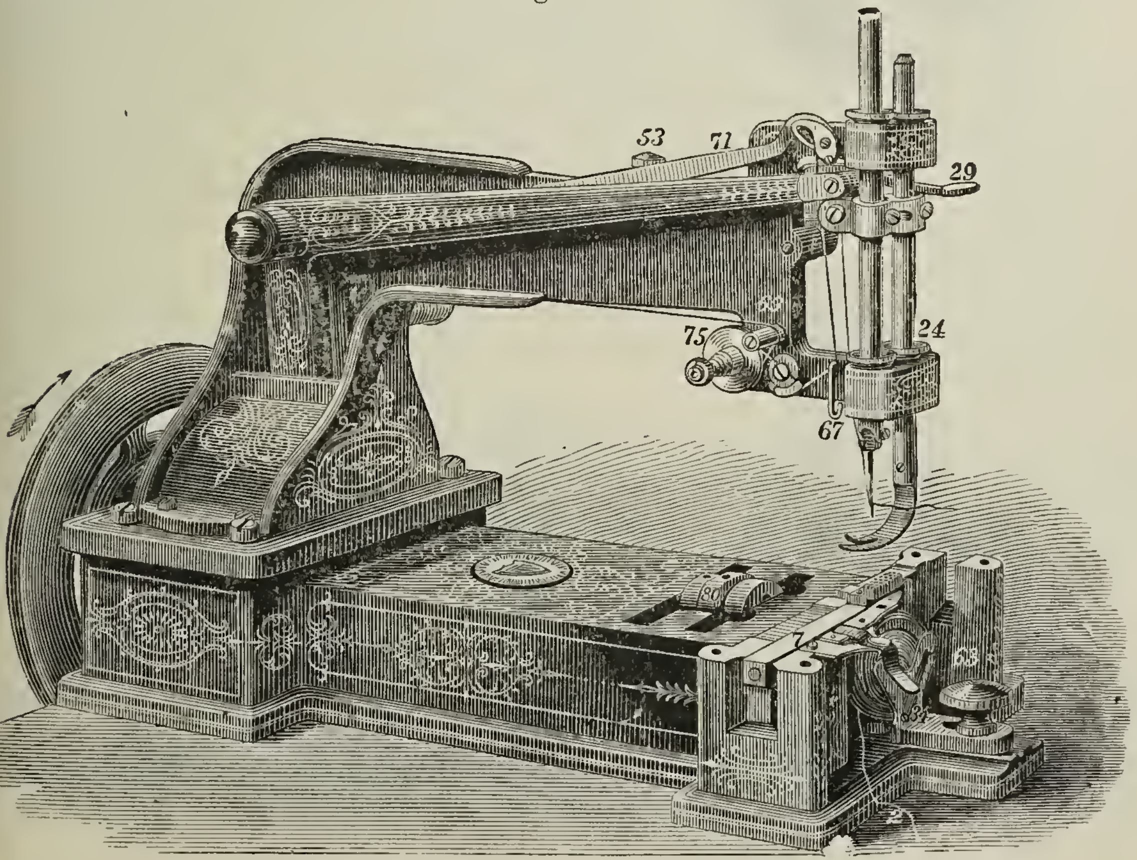


Fig. 22.

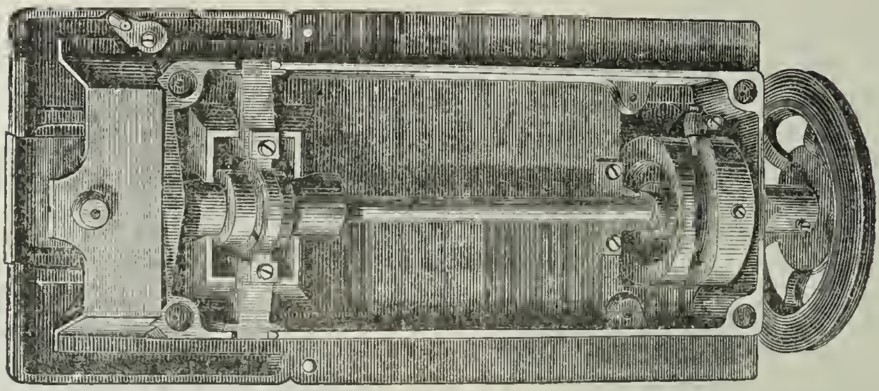


Fig. 22 gives a view of the machine underneath, showing a strong horizontal shaft, 12, upon which are the driving-pulley, 11, and a cam, 4, which serves the double purpose of imparting motion to the needle-arm and the independent take up. It also shows the mechanism for driving the hooks with disk, 81, and flange, 15, with yoke, 80; also the take-up cam, 5, with collar, 14, and take-up connection, 73.

Fig. 23.

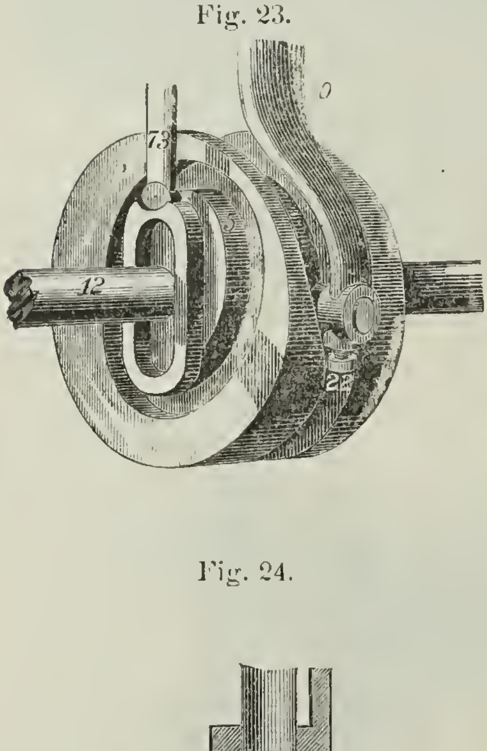


Fig. 23 gives an enlarged view of a section of the driving-shaft, 12, on which is seen the driving-cam, 4, with section of needle-arm, 30, and take-up connection, 73, with cam-roll adjustment, 22, and take-up-cam groove, 5.

Fig. 24 is a view showing shafts, 12 and 18, for driving the hooks, with a section of flanges, 15 and 82, with disk, 81, and yoke, 80, together forming a very ingenious device for giving the proper time to the hook.

Fig. 24.

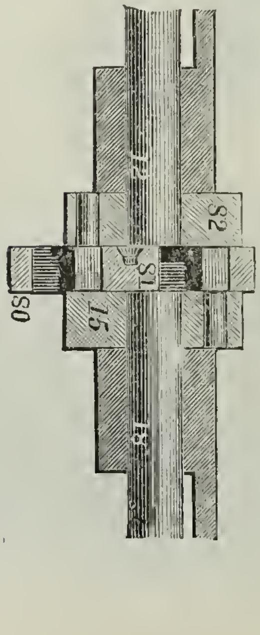


Fig. 25.

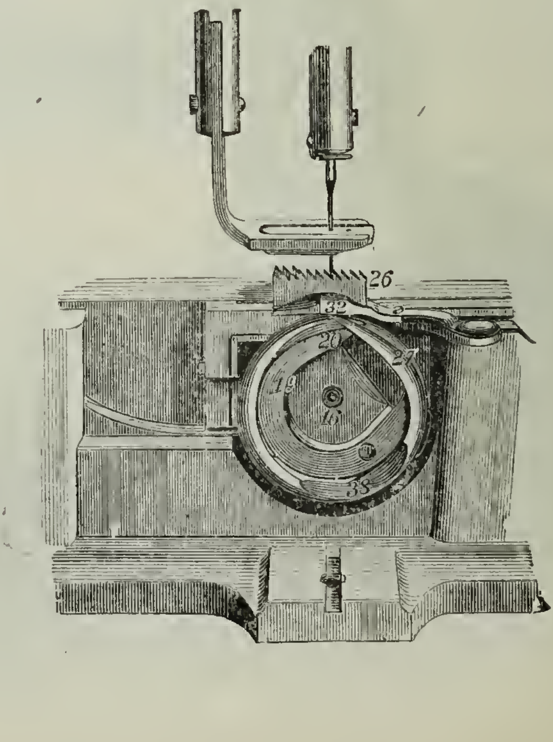


Fig. 25 is a sectional view showing the rotating hooks at 19 and 20, the bobbin-center upon which bobbins are wound at 16, the feed at 26, the stitch-regulator at 27, the loop-guard at 32, and at 38 the bobbin-cavity.

In this machine they have discarded the curved needle, and have substituted a short, straight one—a necessity where great penetrating power is required, as in machines of this class. It is constructed so as to admit of a high rate of speed.

These machines, like all others exhibited by this company, are well made, and in their hands will become popular.

(60) Remington Sewing-Machine Company, Ilion, N. Y.—Passing through the English department to the Machinery-Hall there could be found, running by steam, side by side with the American machines already mentioned, one called the Remington Empire, a machine recently brought out by the celebrated gun-manufacturers of Ilion, N. Y., and, notwithstanding its late arrival at the Exhibition, it received its full share of notice. It is simple, and has the appearance of durability, and will be well made, as this company has a high reputation to maintain.

Much of the original "Empire" has been taken out of it, and details embodying improved principles have been substituted. This work will go on until perfection is reached, as the Remingtons do not turn back, and the public will not fail to be benefited by their experience.

4. Did time permit, volumes could be written upon this subject, relating as it does to one of the largest manufacturing interests in the country, but it would be largely a reproduction of former reports. It is therefore enough to notice in a general way all the exhibitors in the group with which this report has to do, calling attention especially to the comparatively few new improvements exhibited.

The manufacture of sewing-machines seems to have quite early fallen into good and competent hands, and so thoroughly well was their work done that the past decade has been devoted not so much to new improvements as to increased production of already well-nigh perfect machines. As a result, there are but few important or valuable changes to note.

In the sewing-machine-attachment department, however, there is quite a different state of affairs, and to notice all the new departures made therein would be next to impossible.

From extended researches while in Europe, the writer found nothing tending to discourage American sewing-machine manufacturers, unless it was the fact that large numbers of very poor copies of their machines were being thrown on the market at greatly reduced prices, which may make competition a little sharper for the time, requiring more exertion on the part of our makers to find a ready market for the hundreds of thousands of machines exported annually. The public, however, are learning to discriminate in favor of the genuine American machine, when offered beside a poorly made imitation; and while several of our oldest companies are now firmly established as manufacturers in Great Britain or on the Continent, those which are compelled to remain behind have only to maintain their high reputation for perfection of mechanical skill, as shown in the superiority of their machines, to hold not only what they have already gained, but to largely extend this industry.

In this report, the writer has tried to be impartial, believing with the jury, as the nature of their awards attests, that all are entitled to credit and encouragement, and that no one machine possesses sufficient merit over and above all others to warrant a special award.

CHAPTER II.

AMERICAN METHODS AND MACHINERY OF MANUFACTURE.

ORIGIN; WORK IN THE FOUNDERY; THE MACHINE-SHOP; BLACKSMITH'S WORK; ASSEMBLING AND ADJUSTING; METHODS OF SELLING.

5. ORIGIN.—A brief description of a few of the many automatic and other labor-saving machines that are recognized as indispensable in the economical and rapid production of all the first-class American sewing-machines should not be devoid of interest in this connection, particularly as the leading position we occupy in the manufacturing of all kinds of small machinery is largely due to their introduction, together with the various ingenious tools and fixtures adapted to them for producing with the necessary precision the parts of machines by duplication.

It is believed that this system was first introduced and adopted in the working of metals in the early years of the present century, in the manufacture of fire-arms; first at the United States Armory in Springfield, and then at the private armories of Colonel Colt and Eli Whitney, since which time they have become recognized as indispensable.

Here the question naturally arises: Why have American mechanics and manufacturers been the first to apply the advantages to be derived from this system? and the answer is undoubtedly found in the fact that, owing to the greater price for materials and the higher rate for labor, employers, in order to compete with foreign manufacturers, found it necessary to devise some means whereby they could dispense with a portion of the latter element of cost. Then, again, the system of contracting has of late become almost universal in this country, by which a comparatively few of the more ingenious and capable mechanics agree to produce at a given rate the greater proportion of metal-work required in our large establishments. This method tends to secure the adoption of all conceivable means of economizing in labor, and at the same time producing work that can pass without loss the rigid system of inspection of which we will speak hereafter.

6. WORK IN THE FOUNDERY.—*Molding.*—To begin at the foundery, which is usually the starting-point in the manufacture of sewing-machines, we find more work accomplished by one comparatively unskilled hand in preparing the molds or impressions in the sand to receive the molten iron that cools into the finely wrought beds or other parts of the machine than could have been done with four times the labor ten years ago, and also with a greater degree of uniformity. This is largely due to the introduction of new and novel molding-machines, of which there are several makers. To economize in the article of sand, and to save time in manipulating, there have been many improvements made in the form

of the flasks, and in their construction. In the fabrication of these, iron has almost entirely taken the place of wood. In short, there is no part of foundery-work that has not much undergone important and desirable changes during the past few years; so that, in place of the old dark, damp, and illy ventilated structures, presenting a scene of confusion, in the midst of which the visitor groped in fear, breathing either chilling damps or poisonous gases, can be found light and airy buildings, through which one may pass without danger or discomfort. Modern machinery here also has taken the place of "bone and muscle," and the management is thus made easy and pleasant.

Annealing.—From the foundery proper the next step is to the annealing department, usually in close proximity to avoid all unnecessary handling. This department is an indispensable adjunct to founderies producing small castings where a great amount of machine finishing is required, as hard or uneven spots in the metal, the effect of poor stock or chilling in the manufacture, will often cause serious delays and expense. Until a late period, charcoal in a pulverized state was considered a prime necessity in which carefully to pack the material to be annealed, and it was subjected to a slow, tedious process of heating and cooling which was both expensive and unsatisfactory. Now the pieces to be treated are snugly packed in pots or boxes filled with refuse sand from the foundery, upon which, to form a crust to exclude the air, a sufficient quantity of metal chips or turnings are sprinkled. They are then wheeled into position on a car running on an iron tramway, after which the ponderous doors are easily closed by means of weights and pulleys, the fire started in the furnace underneath, from which the heat is conveyed to the annealing chamber, and in a comparatively short time the requisite temperature is reached, after which the fire is allowed to go down and the ovens cool gradually.

Cleaning.—From here the castings go to the tumbling or cleaning-rooms. Here too marked improvements have been made. Instead of the former slow and expensive process of filing off the scale and the rough edges, they are placed in large revolving cylinders, the smaller pieces loosely with irregularly formed "chints" which, in moving with the castings, rub or grind all the parts and wear them smooth. The heavy castings undergo the same process, differently applied, for to put them loosely in the revolving cylinder would result in great loss from breakage. To overcome this difficulty, they are secured in position and revolve with the cylinder, allowing the material used to clean them to fall upon and strike every part of their surfaces. This simple process has saved thousands of dollars yearly to some of the larger manufacturers. This leaves but the sprues to be removed, which is done, not by filing, but by rapidly revolving, cutting, or grinding wheels of emery or other material.

7. WORK IN THE MACHINE-SHOP.—From here the castings are taken to the "machining" department, where they receive the treatment each piece

requires. To avoid confusion, but a few of the more important and familiar parts of the machine will be followed through the process of finishing.

The bed.—First, the bed, the foundation to all machines, is taken to a planing or milling machine; the bottom and edge are straightened or spotted to give a starting-point that will serve as a guide or stop, against which it must rest in the various machines and fixtures through which it passes. This secures uniformity in the various cuts, and preserves the form intact, at the same time dispensing with all blocking or "shimming." It is then ready to go to the planing-machine, to be faced off on the surface. This is accomplished by fastening a large number to a fixture which is securely bolted to the moving platen or carriage of the planer, which is then set in motion, moving horizontally forward and backward, passing under one or more cutting-tools made of very hard steel, and which are firmly held in a clamp that slides on a cross-head placed horizontally over the carriage, and is fed to its work by a screw moving automatically, which may be gauged so as to take more or less feed, as the nature of the work requires; the feeding being obtained on the reverse movement, while the tools are raised to avoid unnecessary wear. If the piece is the bed of a shuttle-machine, it is next taken to an automatic milling-tool, where it is firmly held in a vise or other fixture, and, passing with the carriage under revolving mills or cutters, the teeth of which are formed so as to give the desired shape, it comes out ready to receive the shuttle, again avoiding all expensive hand-chipping or filing, and affording the greatest possible degree of uniformity. This process is repeated on similar machines to remove all surface-material.

Profiling-machine.—Where irregular or intricate cuts are required, the profiling-machine is often used to advantage, and as it is comparatively a new machine, a description will not be out of place here. It has a bed not unlike the common lathe, upon which a carriage moves freely backward and forward. On the carriage is a fixture, to which is fastened the piece to be "machined." Attached to the carriage also is a piece of steel, called a former, in which is cut the exact form of the required product. Running up from each side of the bed are two uprights, connected by a cross-head, upon which a carriage moves above and parallel to the lower bed; and "gibbed" to this are two or more vertical moving heads, each containing a vertical revolving spindle, in the lower end of which are held the mills or cutters made in shape to conform to the cuts to be taken. In these heads are sockets, which receive and hold in position a guide or former-pin, which is brought down to position with the cutter in the work, and the pin in the former. Here it is secured at the proper elevation by a latch, while the operator, by means of two cranks attached to spindles, on which are pinions moving in two racks, one on the upper and the other on the lower carriage, by this compound movement, has perfect control over the carriage on which the former and work rest, as well as the one containing the cutter. This enables the operator to traverse the former and produce the exact form on the work in hand. On removing the latch, the spindle, with the cutter and guide-pin, is raised, by means of a spring, out of the former and work, when the finished piece may be taken out.

Some of the larger manufacturers have special automatic machines of this class which are adapted to single operations, running on the same work constantly; and they are found to be the most economical in the end, as they require but little attention, and turn out a large quantity of uniformly perfect work.

The drill-press.—The bed next goes to the drilling-machine, and is secured in a fixture, called a jig, in which are a series of hardened bushings, corresponding exactly in position and size with the perforations needed in the bed. The drill-press is usually constructed with a main upright column, grooved to which is a vertical carriage, upon which is a horizontal table made to receive the jig and the article to be drilled. Attached to the column above the table are the requisite number of vertical revolving spindles, in the lower end of which are secured the different sizes of drills required. These are not the old-fashioned flat drills which are in use to this day in Europe, but are delicately formed twist-drills, that cut with wonderful accuracy and rapidity. With one hand the operator guides the work and jig to the proper drills, while with the other hand or foot the table and work is raised, forcing the drills through the bushings and into the material. This is effected by means of a lever connected to a shaft, on which is a pinion working in a rack attached to the vertical slide, on which rests the table and jig containing the work. The number of spindles and drills is limited only by the number of holes to be drilled. The advantages of this method are obvious, as all the work is uniform and in exact duplicate. The writer has seen one set of jigs that has drilled one hundred thousand beds containing six hundred thousand holes. These and similar operations are repeated until the bed is ready to receive the arm-post. In the machinery of both of these pieces large numbers of these and other expensive machines are required.

Finishing.—The bed and arm-post are now fastened together and taken to the japanning-rooms, when, after receiving a coat, it is placed in the drying-ovens, when it is subjected to a heat of 350° F. After remaining there for several hours it is allowed to cool, and is then taken to the ornamenting-rooms, where it is quickly ornamented by means of flexible type and other labor-saving devices. If the machine is to be of the highest class, it is usually decorated with pearl. This requires that the article be placed on the surface of the metal in form to suit the design, after which it is built up and fastened with a number of coats of japan, then rubbed down to a good surface, the same as in *papier-maché* work, after which the forms and colors are brought out with gold leaf and tints. It is then varnished with hard gum varnish, and again subjected to a heat of 250° for several hours.

Making the cam.—It is now taken to the assembling-room, where it may be left for the present, while the making of the cam that imparts motion to the needle-arm is described. This piece, after being thoroughly annealed, is tumbled and cleaned, then centered and drilled, usually on a drill-lathe with a number of spindles, so that the hole may be finished without a change in machines. From this it goes to a common engine-lathe, where it is dressed down to the proper dimensions, when it is ready for the cam-cutting machine, which is to cut the grove to receive the roll, which, attached to the needle-arm, must give the required time to form the loop, and admits of the passage of the shuttle or hook through the same. This must be accurately done, as the slightest imperfection will destroy the harmony of movement so essential in the sewing-machine.

To effect this, the blank casting is first drilled on its face in the line of the groove, to get a starting-point for the milling-tool, which is to remove most of the stock, after which it goes to the grooving-machine, which, in its appearance, is much like the ordinary engine-lathe, having a long horizontal bed on which is fitted a cross-carriage containing a spindle, on the end of which the blank is secured. On an end of the bed, at right angles with the spindle, is a common lathe-head containing the milling-tool. This is made to revolve rapidly while the mill is forced into position in the hole in the blank by means of a screw-feeding mechanism at the rear end of the spindle, when the cross-spindle is made to revolve with the blank, at the same time moving horizontally to suit the desired curve in the cut. This is accomplished by means of a former on the spindle, having the exact *fac simile* of the impression in its face that is required in the cam, and into which a hardened roll enters, which is attached to a stationary stud that forces the former, as it revolves with the spindle and blank, to follow the cut in the former, thus leaving the corresponding impression in the blank, and accomplishing the apparently difficult operation with perfect ease and uniformity. Ordinarily this machine has on either end of the bed a separate set of milling-engines, so that while one set is making the rough cut, the other is finishing it to a nicety by changing the blanks from one spindle to the other.

8. WORK IN THE BLACKSMITH-SHOP.—Another important change in the manufacture of sewing-machines during the past ten years has been gained by the introduction of improved machines for forging those more delicate parts in which strength as well as lightness of construction is required, and in which these requisites cannot be attained with cast or malleable iron. In order to describe this method, we will ask the reader to follow that familiar piece known as the shuttle through the first stages of its manufacture.

The shuttle.—Formerly the shell was forced into shape from sheet-steel, after which the two ends that hold the bobbin-centers were shaped and carefully fitted in position, where they were secured either by soldering or brazing, leaving them liable to jar out with the constant hammering to which a shuttle is subjected, especially when run rapidly either by foot or steam power. Now the shuttle-blank is made from one piece of steel, and with one blow it assumes a shape that by the old method required much time and patience to secure. The shell and both ends, being formed together, can never be separated. After being shaped it is trimmed and washed in a solution of vitriol to remove the scale formed in forging; then it is placed between two dies (male and female) of the proper shape, and is subjected to a powerful pressure which forces the metal to yield to the requisite form, after which the finishing is made comparatively easy.

This is only one of the many parts of the machine in which drop-forgings have superseded cast iron, and no well-regulated establishment should be without a set of this important machinery, the utility of which will be readily comprehended.

The bobbin.—Another small but important adjunct of the machine is the bobbin, and in its manufacture great improvements have also been made of late. Formerly the heads were punched from sheet-metal singly; the hole to receive the spindle was also punched; the wire from which the spindles were made was straightened and cut to lengths; after which each end or journal was turned separately and hardened, and the rough ends forced into position, and then turned down to the proper size. This was a tedious process, as the delicacy of the parts made the handling and the machining difficult. With the recently improved automatic machines invented by C. M. Spencer, of Hartford, Conn., their manufacture is made easy and comparatively cheap. A pair of these small and simple machines will produce two thousand bobbins per day with but little attention. All that remains to complete the piece is to force the heads on the spindle, which can be done by a lad at the rate of six thousand per day. These machines take the wire from the coil—one of steel for the spindles, the other of brass for the heads—and straighten it, after which it is fed into the cutter, which turns the journals on the spindles and shapes and drills the heads, dropping them both, finished, into a receiver, without assistance further than to place the coils in position and sharpen the cutters occasionally.

The same inventor has also patented improvements in machines for the manufacture of machine-screws, which enter so largely into the fabrication of sewing-machines, by which he converts a common hand screw-machine into an automatic machine, the advantage being that, instead of requiring a man to work each machine, a single mechanic can keep ten in running-order with ease, thus reducing the cost to a minimum.

The needle.—Among the hundred other parts that enter into the construction of a sewing-machine, many of them pass through equally interesting and ingenious machines and fixtures, of which we will allude to but one; that is, the needle. Small as it is, there has been much thought bestowed upon the machinery and fixtures used in its manufacture. Formerly, the blade of the needle was ground down to the proper size—a trying and uncertain way of effecting this object—after which the grooves were cut separately and the eye drilled. Later, machines for milling the blades worked by hand were introduced. Later still, very ingenious machines were invented, which took the wire from the coil, straightened it, milled it to the proper size for the blades, cut both the grooves at one and the same time, and cut off the needle to the required length, leaving only the eye to be punched and the polishing to be done to make the finished article. These machines are still in use in some of the larger manufactories in this country. There is another method of reducing the blades, for which great advantage is claimed, which is by a swaging process, the wire being fed between compressing dies worked by a system of cams.

It is asserted that the needle is strengthened by compressing the stock, thereby making them more valuable. The Excelsior Needle Company of Wolcottville, Conn., control the patents on this machinery in this country.

9. ASSEMBLING AND ADJUSTING.—We will now collect together all the parts required to construct a sewing-machine at the assembling-room, where we left the bed and arm-post, each of which parts has passed through the preliminary inspection, while receiving the different cuts, and they are now ready to be assembled. Here it is that the advantages of this plan of machining and of inspecting the parts, to see that they are all uniform and consequently interchangeable, over the old way of doing everything by hand, first laying it out with square and dividers, is made apparent.

Here there is no selecting or adapting, as each part is sure to fit the place for which it is intended, and, as a consequence, we find a half dozen men able to assemble and complete two hundred machines in a day—an achievement which without this system would require nearly twenty-fold the force, with nothing like as good results. It is in the adoption of this large amount of labor-saving machinery, and the rigid inspection to which the work is subjected while passing through the various processes, that our great advantage is gained over European makers. Although the original outlay is large, in many establishments reaching into the hundreds of thousands of dollars, we have been able to control this important branch of industry and will for years to come, notwithstanding the fact that some of the more enterprising European makers are introducing these American-made machines into their works, and will continue to do so as fast as the prejudices of the workmen can be overcome.

From the assembling-rooms the machine goes to the adjusting-room, where it is examined and properly timed and tested in a thorough manner at sewing. A sample of its work is attached, to be sent out with each machine, as a proof of its capacity. It is then boxed more or less securely, as the nature of the shipment requires, but always as compactly as is possible.

In the manufacture of the wood and stand work there are to be found machines and fixtures equally interesting and practical, which our space will not admit of noticing. There is, perhaps, no branch of sewing-machine manufacture in which so much of taste is displayed as in the designing and construction of the various styles of cases and cabinets that inclose and embellish the machines. These are elegant articles of household furniture, ornamental as well as useful, and no modern home can well be called complete unless it contains one or more of these faithful servants.

10. THE MODE OF SELLING SEWING-MACHINES ADOPTED BY AMERICAN MAKERS.—To find a ready sale for the vast number of machines manufactured during the past five years, at remunerative prices, has called for even greater energy and skill than has been displayed in their fabrication. Formerly, when the number of machines made amounted to but a few thousands annually, they were sold much as other manufactured goods, from the factories or warerooms, or from a limited number of centrally located salesrooms, with but a small ratio of expense. As the number of makers and machines increased, competition became sharper, and it was found necessary to resort to other methods to reach the masses and to market the increased production. It was at this juncture that some of the larger companies began to open up a market n Europe, which proved very profitable during our war, when gold commanded a high premium. This new field served as a temporary relief to the home market from an overproduction stimulated by the increased facilities adopted in the manufactories. This relief continued but a limited time, as the yearly production increased to fully 500,000 machines. New and untried methods of sale were resorted to; and it was at this time that the expensive system still in vogue was adopted, of canvassing from house to house, not only to receive orders, but to fill them then and there from elegantly finished wagons which penetrated every alley and cross-road in city and country. This called for an enormous outlay in rolling-stock, as well as continued expense in maintaining men and horses, and for the general repairs.

Added to this was the cost attending the instruction, on this vast number of machines, scattered over a great extent of territory, and the collection of the monthly payments, necessitated by the practice of selling machines on lease, to be paid for in monthly installments of five or ten dollars, or even less, as was sometimes required, and many of which payments were not promptly made. These causes have so reduced the profits on the machines that, instead of its being the lucrative business that many have supposed, it is only by constant care, coupled with the strictest economy, that the manufacture and sale of sewing-machines can at present be made to pay a reasonable percentage on the capital invested. A great deal has been said and written against what seems at first to be the exorbitant price charged for sewing-machines; but when it is understood that the nature of the business is such, owing to the expensive methods adopted in selling, the question is naturally asked: Why not put a reduced price on the machines, and sell them in the same manner as other articles of merchandise? This may seem feasible to those unacquainted with the character of the business; but it is a fact easily demonstrated that it is simply impossible. It is for the following reasons:

When a stove or plow is sold, the responsibility and expense to the dealer cease, as the articles are easily understood and utilized. On the contrary, when a sewing-machine is sold, the trouble and expense to the dealer has just begun. He must furnish a skilled operator to give an unlimited number of instructions, ceasing only when the purchaser feels that the machine has been fully mastered, and the great variety of work to which the modern sewing-machine is adapted can be accomplished. To many this is found to be a long and expensive task.

It is also true that the great majority of the purchasers of sewing-machines to-day are wholly unable to pay even a greatly reduced price for the machine on its delivery, whereas by the present system of long credits and small payments this class is enabled often to save enough from the profits of work produced to meet the payments as they mature. By this means thousands have become owners of these machines, which give them increased facilities to earn a respectable livelihood, who otherwise would be compelled to forego their purchase. Should the low-price cash system be adopted, this large and generally worthy class would be cut off from the possibility of purchasing machines, and, as a result, the production would be reduced by at least one-half. So it may be plainly seen that the clamor raised over the high price and large profits in the sewing-machine business arises from ignorance of its true nature, and is without foundation in fact.

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Cuts of Fig. 11, page 18, and Fig. 17, page 20, have been transposed. The former represents the Singer, the latter the Weed machine.

C.

CIVIL ENGINEERING AND ARCHITECTURE.

WILLIAM WATSON.

VIENNA INTERNATIONAL EXHIBITION, 1873.

CIVIL ENGINEERING, PUBLIC WORKS,

AND

ARCHITECTURE.

BY

WILLIAM WATSON, PH. D.,
HONORARY COMMISSIONER OF THE UNITED STATES.

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CIVIL ENGINEERING AND ARCHITECTURE.

ERRATA.

Page 8, line 28, for J J J, read i i i.
Page 9, line 20, for cross-section, read cross-head.
Page 10, line 11–12, for trestle, read chock.
Page 12, line 21, for forty, read twelve.
Page 15, line 10, for 1076, read 1176.
Page 15, line 16, for 7,130, read 71.30.
Page 15, line 19, for full two-centered, read two full-centered.
Page 17, line 42, for 24,000, read 2,400.
Page 23, last line, insert: AWARD. The jury for Group XVIII awarded the medal of merit to Messrs. Malibran et Ed. Morandière.
Page 32, line 45, for Fig. 2, read Fig. 1.
Page 43, line 27, after to, read M. Girard the medal of merit, and to M. Nicolle that of co-operation.
Page 46, line 34, for 71.54, read 78.46.
Page 46, line 34, insert: the lowest level of the waters of the Marne at Condé is 71.54.
Page 48, line 13, omit surplus on.
Page 48, line 15, insert surplus after the word of.
Page 50, line 5, for millimeters, read meters.
Page 53, line 15, for radius, read circumference.
Page 53, line 19, add μ, denotes the coefficient of contraction.
Page 92, line 37, after rain-gauge, read an astronomical clock, a barometric gauge.

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C C C, medical service.
D, baggage.
E, water-closets.
F, omnibus-service.
G G G, } refreshment-halls.
H H H, }
J J J, telegraphic service.
j j j, firemen.
K K K, passages.
L, overseer of the station.
M M, assistant station-master.
N, administration commissioner.

O O O, imperial service.
P P P, ticket-offices.
Q Q, courts.
R, heating-carriage-service.
S, lamp-room.
T T T, store-houses.
U U U, postal-service.
V, express-offices.
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X, straw-stores.
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d d d, custom-house-service.
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g, water-closets.
i, porters.
j, assistant station-master.

k, waiting-room.
l, *m*, room for objects found, &c.
n n, lamp-service.
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G. The plate-iron covering, 0.003 meter thick, fixed to the cast-steel head by two small bolts, thus forming the guide for the endless chain.

H. The frame of the lunette, movable at will along the iron guides to which it is held by the pieces J J, and by means of the rope M.

L is the lunette, striker-off, or unclutching-apparatus movable around the axle K, between the ears O O of the frame H. The lunette when entirely lowered prevents the endless chain from lifting the ram; when, on the contrary, it is hoisted, the first pin, of the endless chain, which comes, meets the claw and carries up the ram ; finally where the ram meets the lunette it becomes unclutched and falls. By this means the ram may be unclutched, at any height desired, according as the lunette is raised or lowered.

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WEIGHTS AND MEASURES.

CONVERSION OF FRENCH WEIGHTS AND MEASURES INTO THEIR ENGLISH EQUIVALENTS.

Measurements of length.

French.		British.
	Meters.	
Millimeter	0.001	0.03937 inch.
Centimeter	0.01	0.3937 inch.
Decimeter	0.1	3.937 inches.
Meter	1	3.2809 feet.
Kilometer	1,000	0.62138 mile.

Measurements of surface.

French.		British.
	Square meters.	
Square millimeter	0.000001	0.00155 square inch.
Square centimeter	0.0001	0.155006 square inch.
Square meter	1	10.7643 square feet.
Square hectare	10,000	107,643 square feet = 2.47114 acres.

Measures of volume.

French.		British.
	Cubic meter.	
Cubic millimeter	0. 000000001	0. 0000610271 cubic inch.
Cubic meter	1	35. 3166 cubic feet.

Measures of capacity.

French.	British.	
1 liter	61. 0266 cubic inches	0. 220215 gallon.

Weight.

French.		British.
1 kilogram	1,000 grammes	2. 20462 pounds.

Measure of force.—1 kilogrammeter = 7. 23314 foot-pounds.
Money.—1 franc = $0. 194 gold.

CHAPTER I.

DESCRIPTION OF THE BOUBLE VIADUCT.

METHOD OF CONSTRUCTION; RESISTANCE OPPOSED TO VIOLENT WINDS; TRIAL TESTS; WEIGHT; COST; MEDAL AWARDED.

(Plates I, II, III, IV, V.)

METHOD OF CONSTRUCTION.—1. LOCATION. The branch of the Orleans Railway between Commentry and Gannat traverses a region intersected by numerous valleys, among the deepest of which is that of the Bouble. Notwithstanding the adoption of very steep grades and the construction of six tunnels whose aggregate length exceeds 1,076 meters, it was found necessary to build a number of viaducts. The most remarkable of these is that of Bouble.

2. This viaduct* is 375 meters long and 66 meters above the level of the stream. It consists of six iron bays, having a span of 50 meters each. The abutment on the left bank, 7,130 meters long, is formed of five full centered arches of 10 meters span each; the abutment on the right bank is 23.70 meters long and formed by full two-centered arches of 7 meters span each.

3. There are five iron piers; the height of each of the three central ones is 55.80 meters above its masonry base. The cast-iron tubes of the piers have an outside diameter of 50 centimeters; their thickness varies from 30 to 45 millimeters. They are filled with *béton* to increase their weight. They are divided into stories, each 5 meters high; each story is strengthened by a system of cross-bracing in plan as well as upon each of the exterior faces in elevation.† Each pier,‡ and each portion of a pier, whether composed of iron or masonry, forms a frustum of a pyramid whose apex is 40 meters above the level of the rails. Thus the tubes have a batter of 25 millimeters per meter in front, and transversely one of 35 millimeters per meter. The dimensions of the top platform are 2.50 meters by 3.50 meters. The lower parts of the columns are strengthened to resist the force of the wind by curved struts which embrace the three lower stories;§ these struts are described with a radius of 24 meters and are imbedded 6.60 meters outside of the tubes, thus giving each of the great piers a total length of 20.60 meters. The various parts of the columns‖ are united by bolts varying in diameter from 45 to 50 millimeters; their number increases from 4 to 8 as we

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* Plate I, Fig. 1. †Plate II, Figs. 1, 2, and 3. ‡ Plate II, Figs. 13, 14, 15, and 16.
§ Plate II, Figs. 2 and 3. ‖ Plate II, Figs. 10, 11, and 12.

descend to the lower stories, which are subject to a greater stress. The cross-braces which unite each story are riveted to flanges cast upon the columns by means of long wrought-iron gussets; this riveting, which was carefully done, is perfectly satisfactory.

For the Sioule Viaduct the wrought-iron gussets were heated and placed in the mould when the columns were cast, an operation which was perfectly successful. The ends of the curved struts* are attached to the piers by great iron bars which penetrate the masonry to a depth of 2.50 meters. The upper part of each bar is bolted upon the outside, thus making a joint which is easily accessible. In the middle of each pier rises a cast-iron column† which, while it stiffens it, serves to hold the ties which connect the intersections of the cross-bracing, thus preventing any spreading. A spiral ladder is built around this central column, thus enabling every part of the pier to be easily examined. A lightning-rod placed in the axis of each pier divides into two branches, which are soldered to the superstructure, one on each side.

4. Each bay is composed of two lattice-girders‡ 3.50 meters apart, resting directly upon the great cast-iron columns of the piers. The height of these girders is 4.5 meters. They are composed of three sets of bars, each of a different shape. One set of diagonal bars is U-shaped, the other is plain; the upright bars which stiffen the truss are 2 meters apart and formed of two angle-irons, which unite and sustain the upper and lower cross-girders,§ M and N. Upon M are placed six double T-bars, 18 centimeters high and 60 centimeters apart. The flooring, which is formed of Λ-bars, is riveted directly upon these. These Λ-irons || are 12 centimeters high and 23 centimeters broad at the base, and weigh 19 kilograms per running meter. This flooring is capable of great resistance. It is left open, thus allowing frequent inspection and repairs. The level of the rails is 45 centimeters above the upper horizontals M M,¶ and these are 55 centimeters below the upper flanges, upon which are placed the sidewalk. The sidewalk is thus raised 10 centimeters above the rails. A passage** 70 centimeters wide has been constructed in the lower part of the truss.†† It extends 300 meters, *i. e.*, throughout its whole length, and from it staircases descend to the interior of the piers. The superstructure rests upon each pier by means of a capital‡‡ turning on a horizontal axis. It follows from this that all permanent or adventitious loads are equally supported by the four great tubes of the pier.

5. The truss was constructed on the left bank of the Bouble, upon a platform 150 meters by 25 meters, with a slope of $\frac{1}{29}$ toward its destined position; it was then pushed forward so as to project 50 meters beyond the abutment, and then pushed successively the same distance beyond each one of the piers, as soon as that pier was completed. The

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* Plate II, Fig. 2.

† Plates I, II, III.

‡ Plates IV, V.

§ Plate V, Fig. 2.

|| Plate V, Fig. 1.

¶ Plate V, Fig. 2.

** Plate II, Fig. 2.

†† Plate V, Fig. 2.

‡‡ Plate IV, Fig. 2.

masonry base for each pier was carefully constructed beforehand; so, also, were the first three stories of its iron superstructure, because the joints of the lower braces required more time and special care. The iron pieces for the construction of the stories above the third were brought over the bridge itself and let down from above to their proper places, as had been done at Fribourg.

6. Numerous photographs, taken at different stages, show the arrangement of the works. One of these is especially worthy of attention, because, when it was taken, the work had been some time suspended on account of the severity of the season; and the truss, projecting 50 meters beyond one of the great piers, had been subjected in this position to violent winds. The perfect stability of these piers and of the parts of the viaduct then finished inspired the greatest confidence in their strength. The time occupied in building was two years and a half.

TRIAL TESTS.—7. The trial tests were made first by a dead load of 4,000 kilograms per running meter; that is, 200,000 kilograms for each span. The second test was by means of a train 74 meters long, with two locomotives, weighing 65 tons each, and six cars, weighing 15 tons each; making altogether 220 tons; *i. e.*, 3,000 kilograms per running meter. The greatest deflections took place upon the intermediate spans, and were as follows:

(1.) *Proofs by a dead load.*

	Deflection. Meter.
All the spans loaded simultaneously	0.019
A single span loaded	0.030
Rise in the unloaded spans	0.013

(2.) *Proofs by the passage of a train.*

	Meter.
With a velocity of 24 to 32 kilometers per hour	0.024
With a velocity of 38 to 42 kilometers per hour	0.030
With a velocity of 47 to 63 kilometers per hour	0.025

(3.) *Compression of the great piers.*

	Meter.
By the dead load	0.005
By the passage of a train	0.004

8. WEIGHT OF IRON USED.

	Kilograms.
Cast iron	151,000
Wrought iron	44,600
Total weight	195,600

Each span of 50 meters weighs 24,000 per running meter, including the roadway. The total weight is thus 120,000 kilograms; the weight of the proof-load is 200,000 kilograms, of which each column supports one-fourth, *i. e.*, 80,000 kilograms; the weight of the pier with the *béton* filling is 280,000 kilograms, one-fourth of which for each column is 70,000 kilograms; hence the maximum load which each column has to support, of which two-thirds is a dead load, is 150,000 kilograms.

The cast-iron columns are 0.50 meter in diameter at the top. The thickness of the iron varies from 30 to 45 millimeters, and the cross-section from 44,300 square millimeters at the top, to 64,300 near the bottom. The lower-curved braces are 50 centimeters in diameter, and have a section not less than 64,300 square millimeters.

PRESSURE UPON THE IRON COLUMNS.—Hence the greatest pressures which the iron in the columns sustains may be thus estimated:

	Kilograms.
At the summit of the piers $\frac{80000}{44300}$	1.80
At beginning of the curved braces $\frac{144000}{64300}$	1.77
At the base upon the curved braces $\frac{150000}{64300}$	2.33
At the base upon the braces and columns united $\frac{150000}{108600}$	1.38

9. COST.—The cost of the piers, the trusses, and the masonry may be estimated as follows:

1. *For one of the piers.*

	Francs.
31,000 kilograms cast iron, at 42 centimes	63,420
44,600 kilograms wrought iron, at 55 centimes	24,530
Total	87,950
Masonry	22,066
Sundries	5,984
Total	116,000

TOTAL COST OF THE VIADUCT.

1. *Iron-work.*

	Francs.	Francs.
Piers, three great and two small ones	399,670	
6 spans	387,900	
Sundries	22,083	
Total cost of the iron-work		809,653
2. *Masonry.*		
3 great piers	66,200	
2 small piers	33,000	
Abutment on the right bank	108,000	
Abutment on the left bank	31,500	
Approaches, &c	51,647	
		290,347
Total cost		1,100,000

Price per unit.—Total length, 395 meters; elevation-surface, 17,900 square meters; total cost, 1,100,000 francs; cost of a great pier, 116,000 francs; cost of the iron truss per running-meter, 1,400 francs.

Whence we have the following results:

Per running meter .... $\frac{1100000}{395}$ = 2, 875 francs.
Per superficial meter of elevation............ $\frac{1100000}{17900}$ = 661. 45 francs.

Per running meter for the central part alone:

	Francs.
A great pier $\frac{116000}{50}$	2, 320
Iron truss	1, 400
Total for a running-meter	3, 720

Price per superficial meter of elevation $\frac{3720}{66}$ = 56.36 francs.

10. These works were executed for the Orleans Railway Company, under the direction of Messrs. W. Nordling, Chief Engineer, Delom, Engineer of the Iron-work, Geoffroy, Engineer of the Masonry. The iron-work was made by Cail & Co.

Award.—The jury for Group XVIII awarded the Medal of Progress to Messrs. Nordling and Delom.

CHAPTER II

DESCRIPTION OF THE NEW TERMINUS AT PARIS, (PARIS AND ORLEANS RAILWAY.)

SITUATION; BUILDINGS OF ARRIVAL AND DEPARTURE; COVERED CENTRAL HALL; IRON ROOF OF GREAT SPAN; DETAILS OF THE WORK; COST; MEDAL AWARDED.

(Plates VI, VII, VIII.)

11. The successive developments of the various branches of the Orleans Railway have given the Paris Railway terminus an importance which was entirely unforeseen. After twenty years of service the old terminus had to be rebuilt.

12. BUILDINGS FOR THE ARRIVAL AND DEPARTURE OF PASSENGERS.—The building for the departure of passengers constitutes the most important part of the construction; it consists of a central pavilion, occupied by a grand vestibule and the various ticket-offices. To the right and left are two wings, each 60 meters long, the first containing the waiting-rooms, and the second a hall for the registration of baggage. An iron portico, 6.50 meters wide, extends along the front and wings. From the ends of these wings project two others, at right angles to the first, in which are placed a refreshment-room, post-office, a telegraph-office, the apartments of the station-master, etc. The building for the arrival of passengers is as long, but narrower, and of simpler construction; it contains a vestibule and rooms for the examination and distribution of baggage. In the wing, at right angles to the main building, are placed the express-offices, the custom-house, and different accessary services. The court of arrival, 190 meters long and 40 meters wide, is covered for one-third of its extent, and has an awning along the sides of the remainder.

13. CENTRAL HALL.—The width, 51.50 meters, which separates the two buildings of arrival and departure, is occupied by eight tracks and two platforms. A roof of a single span covers this space, and is prolonged 100 meters beyond to the end of the *messagerie* sheds, to cover the goods put on the intermediate tracks. By its great dimensions, and its exceptional span, this roof is one of the most attractive portions of the edifice. Its total length is 280 meters, its span 51.50. The trusses, 10 meters apart, are composed of lattice-rafters with angle-irons and sustained by cast-iron struts and wrought-iron ties, according to Polonceau's system of triangulation.

* Cast-iron open-work corbels receive and support the extremities of the rafters. The purlins which unite the trusses are made with flat braces and angle-irons, like the rafters. Their lower flange is an arc of a

circle, so that the purlin has less thickness in the middle than at its ends. This form of purlin is more agreeable to the eye, and has the advantage of bracing more strongly the rafter, which is embraced in its full height. The weight of the iron roof is 1,300,000 kilograms. All the dimensions have been calculated, so that in no point, not even in the tie-rods, does the tension exceed 6 kilograms per square millimeter.

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* Plates VI, VII, and VIII show this terminus in plan, elevation, and section.

14. The time of construction was four and a half years, which will not appear long when we consider that, as the new terminus had to be constructed upon the site of the old one, no building could be demolished until it had been replaced; so that the new constructions could only go on by successive portions, in the face of numerous difficulties.

The ground upon which the structure was built was very unfavorable for a foundation. It was necessary to make excavations to a depth of from 8 to 11 meters to find a stratum solid enough to build upon with security; at these depths, on account of the close proximity of the river and the permeability of the soil, much water had to be pumped out. This kind of work, which was applicable to more than two kilometers of stone wall, was accomplished without accident, but not without great expense.

15. The raising of the trusses of the great hall was one of the most delicate operations of the construction. It had to be done over the platforms and tracks in use without interrupting the traffic. The difficulty was very happily overcome by the Creuzot Company by means of a rolling scaffolding of the same width as the roof, having a platform on a level with the springing lines. Upon this platform were the lifting-engines. This apparatus afforded every convenience for putting together and raising the entire roof, leaving free the platforms and all the tracks, except those on which it moved.

	Square meters.
Surface built over	12, 250
Surface covered by the iron roofs and awnings	27, 422
Open spaces	32, 172

16. Expenses:

	Francs.
Land	8, 350, 000
Administration-building	1, 640, 000
Station proper	6, 900, 000
Accessory works	1, 110, 000
Total	18, 000, 000

It may be interesting to know that the cost of the great hall, covering 14,714 square meters, was 1,030,000 francs, or 70 francs per square meter covered. The above work was projected and executed by M. Sevène, Chief Engineer of the company, and M. Louis Reynaud, its principal architect, to whom is due the architectural portion of the work.

Award.—The jury for Group XVII awarded the Medal for Progress to Messrs. Sevène* and Reynaud.

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*I am indebted to M. Sevène, Professor in the *École des Ponts et Chaussées*, for valuable drawings and information.

CHAPTER III.

DESCRIPTION OF THE IRON ROOF OF THE ROUND-HOUSE AT MONTROUGE, PARIS, (ORLEANS RAILWAY COMPANY.)

General dimensions; Method of construction; Cost; Medal awarded.

(Plate IX.)

17. The increasing business of this company recently made it necessary for them to construct a round-house, having an interior diameter of 45 meters, to contain 16 large locomotives, and to leave a central space, 17 meters in diameter, for the great turn-table. The locomotives were of particular type, 9.80 meters long and 3.35 meters wide. For their accommodation it was decided to cover the whole of this space with a circular iron roof, resting on the exterior walls, and having no interior support, constructed as follows: The great rafters united by a series of concentric circles were to rest below directly upon the angles of the exterior polygonal wall, and at the top upon the crown which supported the lantern; the external thrust upon the walls was to be received and supported by a polygonal chain.

18. General description.—The great polygon,* which rests upon the exterior walls, is 45 meters in diameter; it is formed by three iron plates, each 0.30 meter by 0.015 meter, thus giving a section of 135 square centimeters. The upper circle, which carries the lantern, has a diameter of 7.48 meters.

The sixteen rafters are 20.67 meters long; they are formed of a web 0.008 meter thick, bordered and strengthened by four angle-irons. Each rafter rests with one end against the lower chain and the other upon the upper circle; they are united with each other and supported by nine intermediate concentric circles which offer a solid resistance to bending or change of form. For this purpose each one of the joints is stiffened by squares and gussets strongly riveted to both the rafters and circular braces.

The upper circle, as it is subjected to a considerable strain, has received dimensions somewhat greater. The uprights of the lantern are formed of iron plates arranged to resist in every direction, and well united to the circles which sustain them. The lantern is formed of sixteen little rafters united by two concentric circles; the exterior circle is 7.48 meters in diameter. A portion of the wall has been removed, and in this space the roof rests upon four columns erected at the angles of the great polygon, to the tops of which the lower chain is firmly attached. In order that these columns should not be broken by sudden shocks, they were made of iron plate rolled into half cylinders and riveted together.

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* Plate IX.

19. To raise this roof, cast-iron bearings were fixed at each of the angles of the polygon; these bearings served to receive the great chain which formed the base and the key to this construction; then all the parts of this chain were united and put in place with the greatest care. A mast, 17 meters high, was raised in the center, and each rafter having been put in position at its base was raised to its final position by a long piece of timber which rested upon the walls, and was united to the central mast and sustained by intermediate props. When all the rafters had been arranged, the upper circle was placed which united all the upper ends. Each of the concentric circular braces or purlins, was then easily united to two contiguous rafters by means of light scaffoldings suspended from the principal pieces. Each piece was made and riveted throughout at the iron-works; a few of the principal pieces were riveted together when placed in position, but all the others were united by bolts. This roof has been exposed to very violent winds; it has also been covered with snow 16 centimeters thick, and has resisted perfectly.

20. GENERAL DIMENSIONS.—The inclosed wall is constructed upon a polygon of sixteen sides; the circumscribing circle is 46 meters in diameter; the wall is 50 centimeters thick; the radius of the polygon, made by the iron chain which sustains the rafters, is 22.50 meters. The surface of this polygon is 1,545.92 square meters; the perimeter is 140.46 meters. Each side is 8.779 meters long, and each sector has a surface of 96.62 meters. The upper circle circumscribing the lantern polygon, has a radius of 7.48 meters; the roof slopes 25°; the length of each rafter is 20.67 meters; the intermediate circles are spaced in plan 1.83 meters, in space 2.06 meters. The lantern has ground glass 0.0045 meter thick; the roof is covered with slates 60 by 30 centimeters. These pieces present an excess of strength in order to give great stiffness to the system, consequently the stress on the iron is almost everywhere less than 6 kilograms per square millimeter of section, and in no case does it exceed 8 kilograms per square millimeter.

21. The cost of the iron frame-work of the roof may be thus stated:

			Francs.
Wrought iron....	113, 437	kilograms, at 0.59 franc......	66, 927. 83
Cast iron........	3, 550	kilograms, at 0.38 franc......	1, 349. 00
Total......	116, 987	kilograms.	68, 276. 83

This is per superficial meter of space covered, limited by the lower chain, a weight of metal of $\frac{116987}{1546} = 75.67$ kilograms, and an expense of $\frac{6827683}{1546} = 44.17$ francs.

22. This work has been done under the direction of M. Morandière, General Inspector *des Ponts et Chaussées*, by MM. Malebran and E. Morandière.*

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* I am indebted to M. Morandière for valuable drawings and information.

CHAPTER IV.

DESCRIPTION OF THE IRON VIADUCT OVER THE OSSE.

DIMENSIONS; LOAD; COST; MEDAL AWARDED.

(Plate X.)

23. This work, constructed on the railway between Agen and Tarbes, crosses the valley of the Osse in a right line, sloping 25 millimeters per meter at a height varying from 21.86 meters to 17.54 meters. It consists of an iron viaduct of seven bays; the intermediate bays having a span of 38.40 meters, and the extreme bays one of 28.80 meters. The total length is consequently 249.60 meters. The iron superstructure is supported by two abutments in masonry, and by six double cast-iron tubular piers, each 1.70 meters in diameter and filled with *béton.* This interior mass gives them a stability and an inertia well adapted to resist both the action of the wind and the molecular vibrations caused by the passage of the trains. These columns are formed of successive rings, perfectly bolted together, so as to form a continuous cylinder, which, as it descends, is embedded in a solid foundation and receives above the weight of the two contiguous bays by means of the foundation-plates, which are furnished with guides and friction-rollers.

24. The viaduct has its superstructure inclined 25 millimeters per meter. It has been studied so as to serve as a type, even if the declivity should amount to 0.031 meter. Under these conditions the horizontal component due to the inclination of the plane of the rails, produces a tendency to overthrow the piers, which renders it necessary to sink them deep and to arrange them so as to have the pressure uniformly distributed. The cast-iron tubes have their sections strongly bolted together and filled with *béton*, forming columns which go down into solid strata as deep as is necessary; each column thus forms a cylinder firmly embedded at its extremity. The constant section is also eminently proper to resist any horizontal force, whether it acts in the direction of the bridge, as when it arises from the inclination of the rails, or obliquely, as when it is produced by the wind or by the swaying motion of a train.

Finally, the *béton*, which fills the columns, gives them a stability and an inertia well adapted to resist the force of the wind. If, instead of this arrangement, the piers had been formed of iron trestle-work, it would have been impossible to have prevented some of the principal pieces from being unduly loaded. The load per square centimeter upon the surface of the *béton* is 3.13 kilograms. The maximum transverse stress is 1.32 kilograms per square millimeter for the cast-iron.

25. The total cost of the viaduct is 563,087 francs; that is 2,255.55 francs per running meter, and 112.79 francs per square meter of elevation above the ground. The price per running meter of an iron pier is 1,369.45 francs.

26. This viaduct was constructed under the direction of M. Paul Regnauld, Chief Engineer, by M. Boutiller,* Engineer *des Ponts et Chaussées.* Each of these gentlemen received the Medal of Progress rom the jury of Group XVIII.

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* I am indebted to M. Boutiller for the photograph and valuable information.

CHAPTER V.

RIVER IMPROVEMENTS BETWEEN PARIS AND AUXERRE.

The substitution of a continuous navigation upon the Upper Seine and Yonne, by the aid of movable dams, for the intermittent navigation by flashes.

DIFFICULTIES OF NAVIGATION; SUMMER WATER AND FRESHETS; CONDITION OF THE YONNE UNDER THE INFLUENCE OF FLASHES; DESCRIPTION OF THE METHOD OF NAVIGATION BY FLASHES; FORM AND VELOCITY OF A FLASH; AFFAMEURS; WORKS BETWEEN AUXERRE AND MONTEREAU; DESCRIPTION OF POIRÉE'S NEEDLE BARRAGE; DESCRIPTION OF CHANOIN'S SYSTEM OF FALLING GATES, (BARRAGE À HAUSSES MOBILES;) DÉRIVATIONS OR SIDE CHANNELS; METHOD OF CONSTRUCTING THE BARRAGES; AUTOMATIC HAUSSES; PRACTICAL OBJECTIONS TO THEIR USE; SUCCESS OF THE NEW SYSTEM; LOCKS; DESCRIPTION OF GIRARD'S SYSTEM OF HYDRAULIC PRESSURE SLUICE-GATES; COST; COMPARISON WITH THAT OF THE NEEDLE BARRAGE; THE SEINE BETWEEN MONTEREAU AND PARIS; LOCKS; DESCRIPTION OF THE LOCK AND BARRAGE AT PORT À L'ANGLAIS; COST OF THE WHOLE SYSTEM; INTEREST ON THE COST WITH ANNUAL EXPENSES; MODES OF TOWAGE; TAX ON FREIGHT; COMPARISON OF WATER-WAYS WITH RAILWAYS; MEDALS AWARDED.

(Plates XI, XII, XIII, XIV.)

27. The great navigable route* which unites Havre, Rouen, and Paris with Lyons and Marseilles, by the rivers Seine, Yonne, the canal of Bourgogne, and the rivers Saône and Rhone, presented until recently a defective portion of 190 kilometers. For nine months of the year, from March to November, the descent of freight, especially upon the Yonne, was possible only twice a week by a system of flashing, or artificial floods, coming from the Upper Yonne, with a depth of water varying from 75 centimeters to 1.10 meters, so that loaded boats from the Bourgogne Canal drawing from 1.10 to 1.40 meters, were obliged to discharge at Laroche. The ascending trade was very small, the boats containing only a few tons of merchandise. This navigation, costly, slow, and entirely insufficient, was fatiguing and liable to numerous accidents. Although somewhat less difficult upon the Seine, the navigation was extremely embarrassed, and often interrupted between Montereau and Paris.

28. Since the 1st of September, 1871, the navigation has been continuous between Laroche and Paris, by means of seventeen movable dams, two side channels (*dérivations*) in the Yonne, and twelve movable dams in the Seine. The depth of water in the dams is 1.60 meters, so that all boats drawing less than 1.50 meters may pass in perfect security.

In order to fully appreciate the importance of the improvement of the navigation, by the establishment on a large scale of the movable dams above Paris, it will be necessary to describe the methods of navigation heretofore in use on these two rivers. We will first consider that portion of the Yonne between Auxerre and Montereau. It has a length of 119,586 meters, and may be divided into two sections: first, between Auxerre and Laroche, a length of 27,616 meters, which is as yet navigable by the intermittent system, which will presently be described; second, a section of 91,970 meters between Laroche and Montereau, in which the intermittent system has not existed since 1871, when the movable dams were first raised.

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* Plate XI, Figs. 1 and 2.

The waters are said to be low when they are 50 centimeters above the lowest summer waters; they are ordinarily from 0.50 to 1.50 meters, and at freshet times from 1.50 to 2.50 meters. At 2.50 the tow-paths are covered, and the navigation is interrupted. From 1865 to 1871 the Yonne has had a freshet of twenty days, on an average, per year; low water, one hundred and eighteen days; mean waters, two hundred and twenty-seven days; and for eighteen days the navigation has been interrupted by a great freshet or by ice.

29. FLASHES.—The navigation of the Yonne above Laroche is very variable and precarious. During eight or nine months of the year (from March to November,) navigation takes place by means of a system of flashing, which may be thus described:

In the upper parts of the river the water is ponded up by movable dams, (the construction of which will be presently explained.) A part of one of these dams being suddenly removed, an artificial flood is produced, called an *éclusée.* Barges and rafts, previously collected above the dam, are carried along with the flood down the river. The number of these *éclusées* per year is about 85, and the mean depth of water upon the sand-bars and shoals, which stretch across the bed of the river, is 1.08 meters. The descending flood carries the barges and rafts rapidly down the stream, with a draught of water which varies from 50 to 65 centimeters for the rafts, and from .75 meter to 1.10 meters for the barges. But for the ascending boats there is frequently a scarcity of water, lasting from twelve to twenty-four hours after the passage of an *éclusée.* During this time, the water being below its lowest summer level, it is impossible for the smallest barge to float over the sand-banks which cross the river-bed. From this cause the ascending boats are nearly all empty, or slightly laden. The *éclusées* are managed by employés, called *meneurs d'eau,* who open successively at suitable intervals the movable dams, through which the flood runs with considerable velocity; its effect is felt for about four hours; its volume is about 1,500,000 cubic meters. Below Auxerre the barges descend first, followed by the rafts. In a favorable time the rafts of wood take from six to eight days to descend from Armes to Paris, a distance of 295 kilometers, but the voyage often lasts fifteen, twenty, or even thirty days, on account of fog, wind, want of sufficient water, or other causes of accident, which render this mode of intermittent navigation so precarious.

30. VELOCITY OF AN ÉCLUSÉE OR FLASH.—The instant for opening each movable dam is determined by an empirical rule, which is closely followed. Each dam is closed after the water falls to a certain level. Usually during the summer they are opened twice per week. The velocity of the flash depends upon the declivity and sinuosity of the river, the number of dams, the volume of the flash itself, the wind, and the obstructions of the stream. From Auxerre to Laroche it takes six hours thirty minutes to flow a distance of 27 kilometers, or 1.20 meters per second. A violent head wind might retard the flash two hours. The boats carried by the flash generally go more rapidly than the flash itself, so that they can make short stops and take the same flash again. To understand the form and motion of a flash it is necessary to observe its velocity and depth throughout its whole extent; this has been done by M. Chanoine, at Laroche, and is shown in Fig. 1. This figure gives the level of each point of the longitudinal profile with its corresponding velocity. It shows that the velocity varies from one point to another, and that the top of the flash travels more rapidly than any other point, whether before or behind it. For this especial flash the velocity of the water is 1.33 meters per second for a length of 2,394 meters occupied by the top, while at 3,474 meters behind, the velocity is only 0.53 meter; and it is 1.15 meters at 4,482 meters in front; thus at each instant the highest section of the flash is thrown forward upon the section immediately preceding, which moves at a slower rate. This shows why a boat on the top of the flash will move faster than the flash; but if the boat is in that part of the flash where the velocity is less than 1 meter and behind the crest, it moves slower than the flash and finally falls entirely behind it. We may estimate the effective duration of a flash to be one-half the time it actually takes to pass a fixed point.

31. AFFAMEUR.—Each movable dam remains open only a short time for the passage of the flash and it is immediately closed again to collect the water for the following flash. This closing produces below the dam an abasement of the level of the water which is designated by the name *affameur*. Every flash is thus followed by an *affameur*, which is felt at a great distance down stream; and for from twelve to twenty-four hours following, the water is below its lowest natural level, and the passage of the smallest barge is impossible over the sand-bars which stretch across the channel; for this reason the ascending boats are nearly or quite empty. Nevertheless this navigation, imperfect as it is, has rendered for three hundred years signal service for the economical transportation of wood, etc., at a time antecedent to the establishment of other means of easy and rapid communication. In 1866, from Laroche to Montereau, the freight in boats was 270,699 tons, by rafts 179,230, descending; ascending freight 5,518 tons; total 455,750 tons.

32. ESTABLISHMENT OF A CONTINUOUS NAVIGATION BETWEEN AUXERRE AND MONTEREAU.—Two decrees of the government, the first in 1861, and the second in 1868, ordered the construction of the works

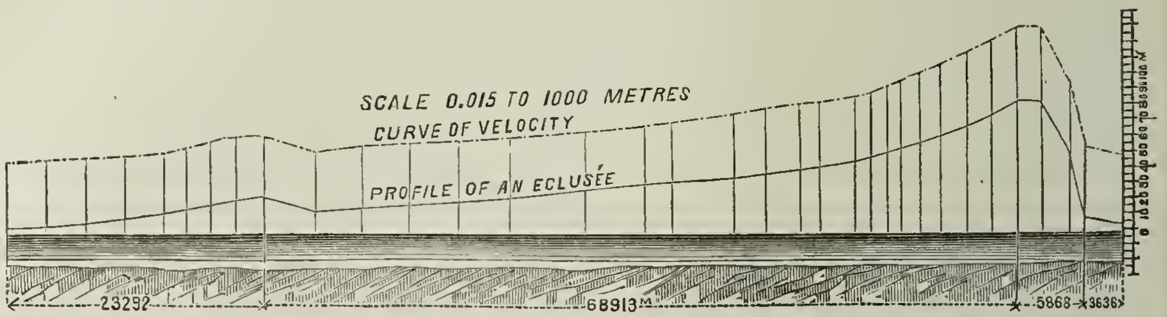

FIG. 1.—Form of an *éclusee* or flash-curve showing its velocity at each point.—Art. 31.

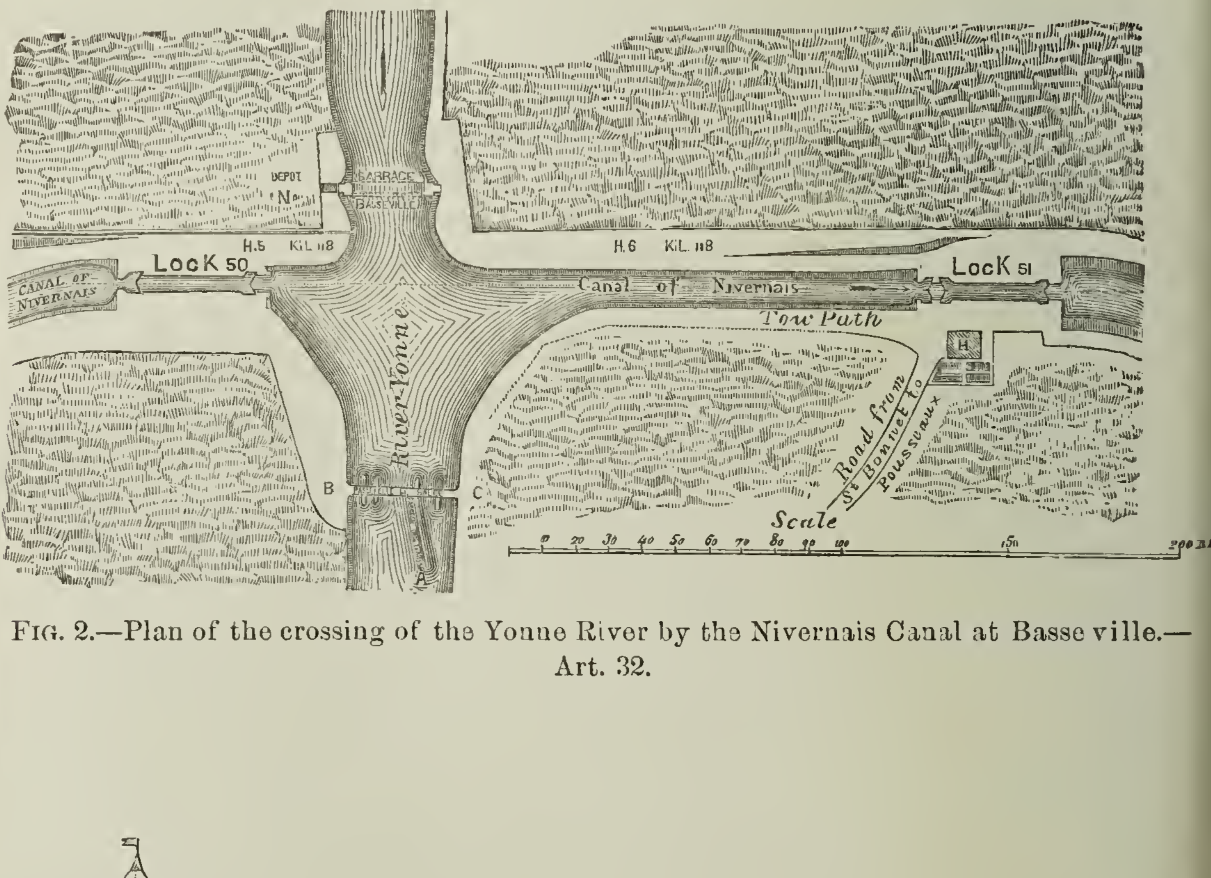

FIG. 2.—Plan of the crossing of the Yonne River by the Nivernais Canal at Basse ville.—Art. 32.

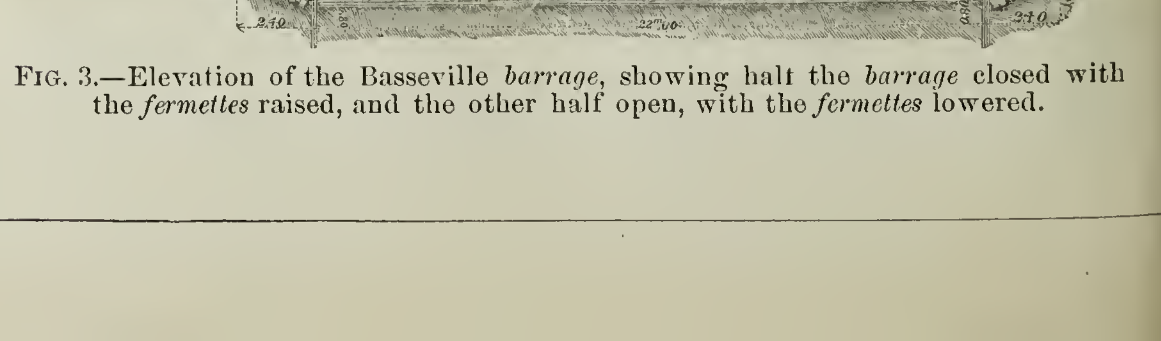

FIG. 3.—Elevation of the Basseville *barrage*, showing half the *barrage* closed with the *fermettes* raised, and the other half open, with the *fermettes* lowered.

necessary to give a depth of water of 1.60 meters, and appropriated for that purpose the sum of 8,200,000 francs. The dimensions of the locks were to be 96 by 10.50 meters. Three locks constructed before that time have somewhat different dimensions.

There are twenty-five movable dams and three *dérivations*, or side channels between Auxerre and Montereau, viz, eight movable dams, of which seven have locks and one *dérivation*, between Auxerre and Laroche; seventeen movable dams, fifteen of which have locks and two *dérivations*, between Laroche and Montereau. Three movable dams are placed at the head of the three *dérivations*. Three of the old movable dams, or *barrages*, as we shall henceforth call them, are needle barrages, called *barrages à fermettes*, of M. Poirée.

NOTE.—In order to give an idea of a needle *barrage*, I cannot do better than to reproduce a description given by the inventor in a lecture at the School of Roads and Bridges at Paris:

Figs. 2, 3, 4, 5, represent the situation and arrangement of the first *needle barrage* ever erected. It consists of a succession of iron frames (Fig. 5) called *fermettes*, placed parallel with the current, and turning around their bases in bearings which are firmly attached to a carefully-prepared bed. The *fermettes* are united above by bars, having jaws or catches at their extremities, (Fig. 14.) Against these *fermettes*, thus united, rests a screen, placed vertically, and composed of a number of wooden battens about 0.075 meter square and 2 meters long, called needles; the bottoms of these needles are placed against the sill, and their tops rest against the *fermette* bars placed near the level of the water, which the *barrage* is intended to maintain. Each *fermette* is trapezoidal; the two bases are horizontal. The lower base is terminated by gudgeons, which are received by two cast-iron bearings, (Fig. 10.) The upper bases support a foot-bridge, used by the lock-keeper to work the *barrage*. The details of the hooks, bars, washers, etc., which serve to unite the *fermettes*, are shown in Figs. 7 and 8. When it is required to open the *barrage*, the lock-keeper and his assistant remove the needles one by one; the bars, planks, hooks, &c., (Figs. 8 and 9,) are removed, and the *fermettes*, turning on gudgeons at their bases, fall into a recess prepared for them below the level of the sill. When it is required to raise the *barrage*, the lock-keeper raises the *fermettes* by grappling for them under the water, reconstructs his foot-bridge, and replaces the needles. The time required to raise the *fermettes* and place the needles, is about one and a half minutes per running meter; and the time to open the *barrage* thirty seconds: for the complete opening and lowering of the water, fifty seconds.

The annexed figures represent the *barrage* of Basseville:

Fig. 2. The plan of the crossing of the Nivernais Canal and the river Yonne, at Basseville.

Figs. 3 and 4. The general elevation and plan; showing half the *barrage* closed and the *fermettes* raised, and the other half open and *fermettes* lowered.

Fig 5. The cross-section of the *barrage;* showing the form of the needle, the *fermette*, and its bearings, the normal level of the canal, and the greatest height of the flashes; the level of the river below, and the level of the mitre-sill of the canal-lock at Basseville.

Figs. 6 and 7. Abutments on the left and on the right of the *barrage.*

Figs. 8 and 9. Elevation and plan of the details for uniting the *fermettes*, as seen from below.

Figs. 10 and 11. Details of the iron-work and gudgeons, showing the plan and the section upon the plane A B.

The three needle *barrages* are at La Chainette, Epineau, and Port Renard. Each of the twenty-two new *barrages* has a pass closed by Chanoine's system of falling gates, (*hausses mobiles du système Chanoine,*[*]) worked by means of a talon-bar and a boat. Thirteen of these *barrages* have an overfall held by *hausses mobiles*, the *hausses* being worked from a bridge resting on a system of *fermettes.* In six, the overfall is surmounted by *fermettes* and needles with a foot-bridge 0.25 meter above the upper bay; one has Girard's system, which will be hereafter explained in detail. The sills of these passes are generally placed 0.50 or 0.60 meter below the level of the lowest water.

33. In order to fully understand the magnitude and value of the works constructed upon the Seine and Yonne, it will not be out of place to give a brief description of the sytem of *barrages* last adopted, taking as an

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[*] The "*barrage à hausses mobiles*"[*] consists of a series of timber gates, framed and strongly clamped with iron,[†] and revolving on the upper part of an iron trestle[‡] by means of two cast-iron pedestals secured to them by wrought-iron screw-bolts, nuts and washers, at between one-half and one-third their height. The support of the gate is a strong wrought-iron trestle, having continuous bars at its bottom and top, furnished with turned journals at each of their ends; the upper journals work in the pedestals, bolted on the timber gates, and the lower journals also work in pedestals strongly bolted down to the basal platform. The body of the trestle in the direction of its breadth, has the form of a trapezoid, being about one-half of the breadth of the gate at the top and two-thirds at the bottom. The height of these trestles is between one-half and one-third the height of the gates; hence, when the trestle is folded down the gate folds over it, and so they lie flat on the platform.[§] When the trestle is raised so as to be vertical, and the gate turned into its upright position, its lower end abuts against a sill which stands four inches above the platform; it then has an inclination down-streamward of about one-eighth of its height; it is supported in that position by a strong wrought-iron strut or prop, (called an "*arc-boutant;*") a revolving bolt passes through the upper end of the abutment-prop, and through two projections formed on the upper end of the wrought-iron trestle. This abutment-prop, when in position, makes an angle of 40° with the horizon. To enable the abutment-prop to resist the pressure of the water against the gate, its lower end is received into a cast-iron shoe[||] open at one side to allow the lower end of the abutment-prop to be drawn out into a guide-plate when the structure is to be lowered on the rising of the flood. A long horizontal bar, called a talon-bar, furnished with projections or talons at suitable intervals, displaces the lower

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[*] This description is substantially that given by Mr. Manning in his report to the board of public works of Ireland. Several inaccuracies have been corrected, and it has been made to apply to the *barrage* at Port à l'Anglais.

[†] Plate XIV, A, Fig. 6.

[‡] A, Fig. 3.

[§] Plate XIV, Figs. 2 and 3.

[||] Plate XIV, Figs. 4 and 5.

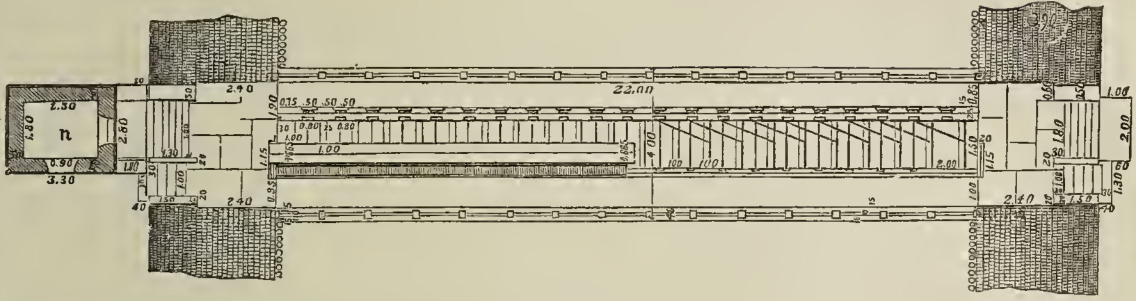

FIG. 4.—Plan of the same.

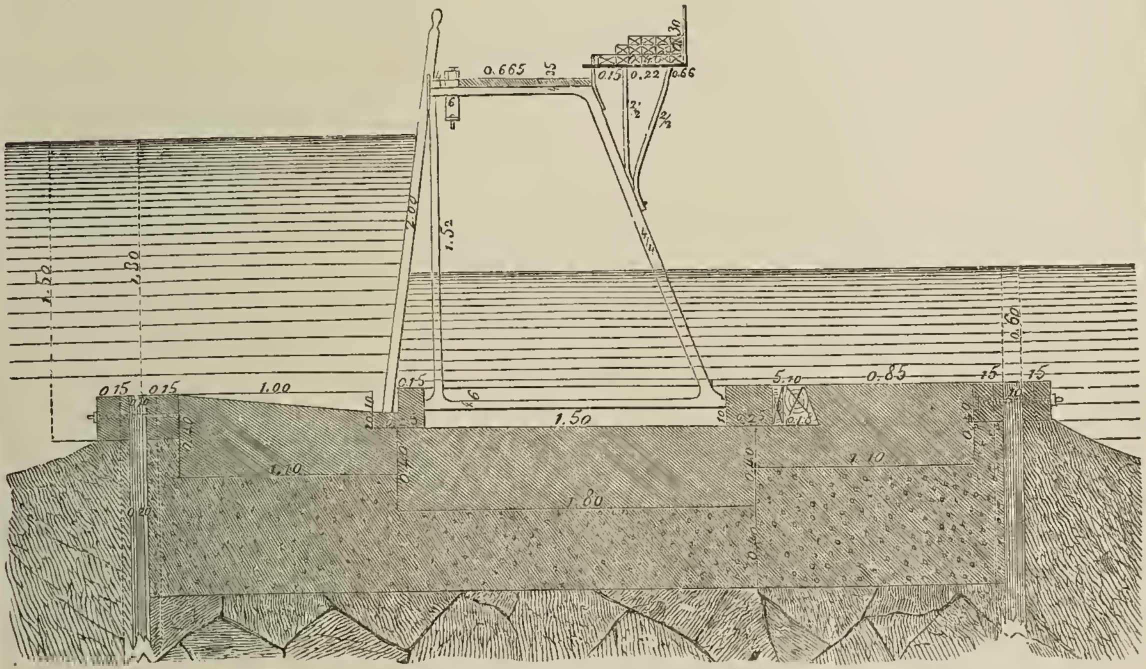

FIG. 5.—Transverse section, showing the needle, the *fermette*, and its bearings.

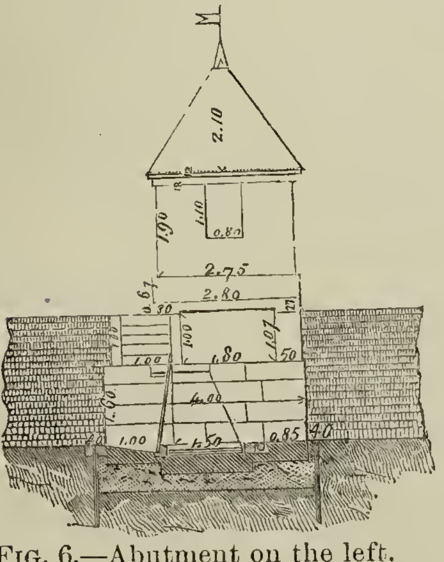

FIG. 6.—Abutment on the left.

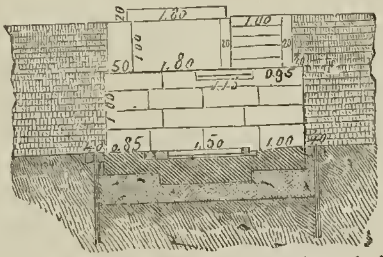

FIG. 7.—Abutment on the right.

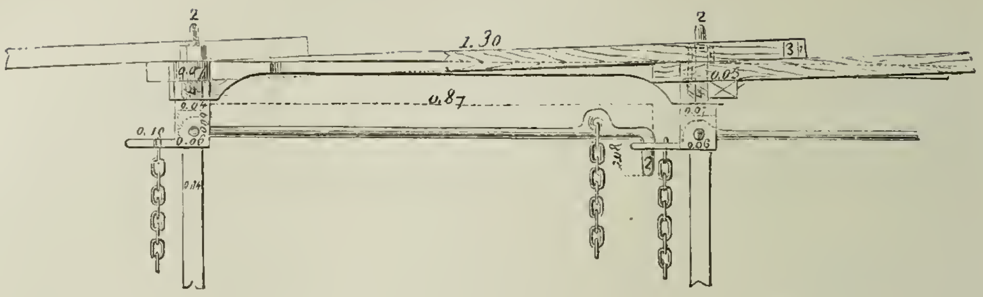

FIG. 8.—Elevation of the details for uniting adjacent *fermettes*, seen from below.

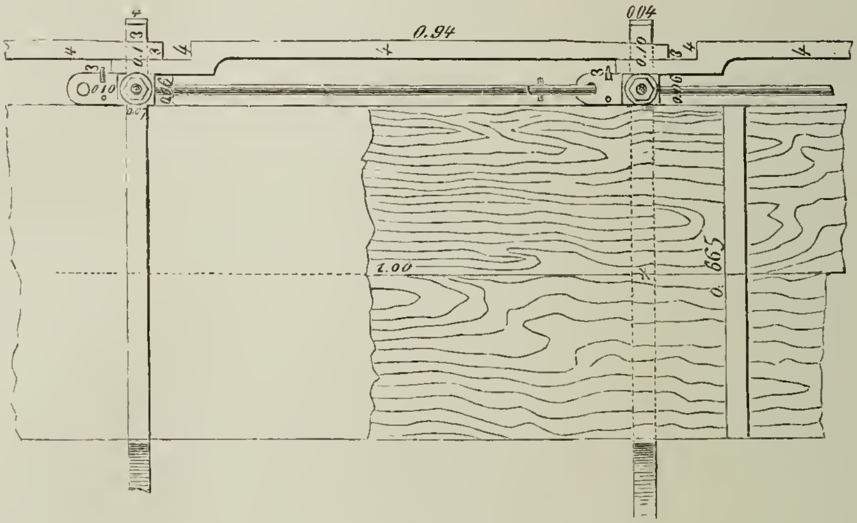

FIG. 9—Plan of same.

Fig. 10 *D. Section on A.B.*

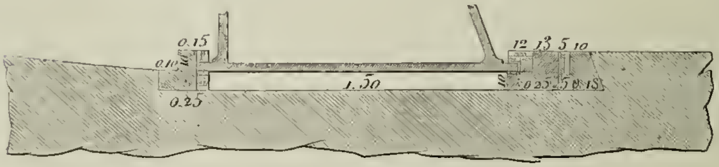

Fig. 11 *D. Plan*

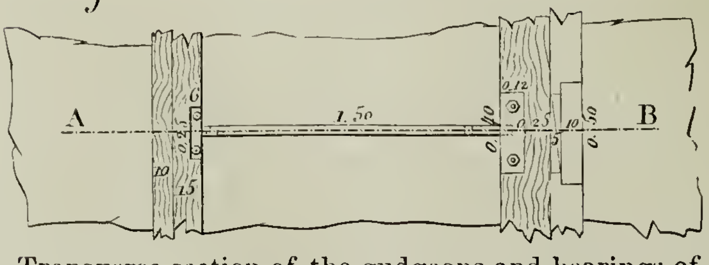

FIG. 10.—Transverse section of the gudgeons and bearings of a *fermette*.
FIG. 11.—Plan of the same.

example one which was personally examined at Port à l'Anglais, near Paris. Plates XIII and XIV.

Plate XIV. A, Figure 1, shows Chanoine's *barrage*, to which are added the iron *fermettes* behind. In the system represented for half the width of the stream the *fermettes* do not exist, but only the gates.

The *barrages à hausses mobiles* differ from the *barrage à fermette* in this, that, instead of any part of it being removed on the rise of the flood, the whole is lowered into the river, piece by piece, upon a solid bed of masonry prepared for its reception, and it there remains until the flood subsides, and it becomes necessary to raise it again to retain a sufficient depth of water for navigation. It is not all of one depth, although level at the top. M. Boulet, engineer of the above work, calls one division the navigable *pertuis*, the second the overfall, and the third the *barrage*, though the first and second have ceased to have their original significations. In times of flood, when the *barrage* is lowered, vessels could go over it instead of passing through the lock.

34. DÉRIVATIONS.—In order to avoid the very winding and dangerous portions of the river, three *dérivations*, or side channels, have been cut, viz:

At Gurgy, 5,007 meters long.

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ends of the abutment-props from the cast-iron shoes while the gates are being lowered. The horizontal talon-bars are moved by capstans at each end of the *barrage*. Now, if the *barrage* is erect and the rapid rise of the flood makes it necessary to lower it, the capstans are manned and the lower ends of the abutment-props are drawn in succession, one at a time, out of the cast-iron shoes; as soon as they are at liberty they slide along the guide-plates, and the supports being then withdrawn from the trestles they and the gates follow the abutment-props, until all rest flat on the platform and the water has full liberty to flow over them.

The gates are raised by means of a boat of suitable construction. This boat is furnished with a crab-engine, placed a little abaft midships, and a large sheave or pulley on or near the head of the stem. When the gates are to be raised the boat is attached to one of the piers.* To the lower end of the gate, now lying prostrate upon the platform, a strong wrought-iron handle is secured. A hook having a long handle or shaft made of timber is provided, and to this hook the end of a long chain is made fast. By means of the handle, the hook is placed in the handle of the gate, the chain is passed around the pulley at the stem-head of the boat and taken aft to the barrel of the crab. By heaving on the crab, the gate is drawn up-stream, the trestle on which it is supported revolves on its axis, the top moving through the quadrant of a circle until it is nearly vertical, and the lower end of the abutment-prop falls into its place in the cast-iron shoe. The chain-hook is then detached from the gate; the lower part is pressed downwards against the front of the main sill of the platform and stands as already stated, with an inclination down-stream, at the top, of about one-eighth of its height. Only one gate can be raised at a time. A space of 3½ to 4 inches is left between each of the two adjoining gates, through which considerable of the ordinary summer discharge of the river flows, when the pond is raised to its regulated height, without forming a cascade over the gates. For the Port à l'Anglais, those portions of the *barrage* provided with *fermettes*, the intervals between the adjoining gates are filled with square needles placed cornerwise. These have given good satisfaction. It is reported, when all the preparations are made, that it takes about five minutes to raise each gate.

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* As seen in Figs. 1 and 2, Pl. XIII.

At Joigny, 3,574 meters long.

At Courlon, 4,134 meters long.

These three *dérivations* shorten the distance from Auxerre to Montereau 11,309 meters. At the head of each *dérivation* there is a lock-gate, to prevent the entrance of the flood-waters. The width at the bottom of each *dérivation* is 16 meters, and its depth below the normal plane of the waters is 1.80 meters; the banks have a slope of 3 meters of base to 2 in height, which gives a width of 21.40 meters at the surface of the water. The tow-paths are from 4 to 6 meters wide, and are 0.50 meter above the highest known floods. The passage under the bridges is narrowed to 10.50 meters, the height of the *intrados* above the water being 5.50 meters.

35. FIXED PORTIONS OF THE BARRAGES.—The width of the foundation of the upper bay of the pass of the new *barrages à hausses mobiles* is from 7 to 10 meters up the stream; its thickness is at least equal to the fall and rarely less than 2 meters. Between Auxerre and Joigny it rests directly upon the rock or chalk. Between Joigny and Montereau the mass is formed of a layer of *béton* poured into a coffer-dam, and upon this mass; after the dam had been pumped out the foundation and bed of the upper bay were built, which is partly of cut stone and the rest of rough stone dressed at the joints. In the bed of the upper bay* are fixed anchors, consisting of wrought-iron bars and cast-iron plates serving to solidly unite the masonry and the wooden sill against which the bottoms of the *hausses* strike. The bed of the overfall of these new *barrages* is usually 4 meters wide, and has a minimum thickness of 2 meters. It is either entirely of masonry or else a wooden coffer filled with *béton* and covered with a masonry pavement.† Below most of the *barrages* there is established a rear bed, or apron, consisting of rocks and artificial blocks, which are sometimes kept in place by lozenge-shaped groups of piles.

36. MOVABLE PORTIONS OF THE BARRAGES.—The navigable passes of the twenty-two new *barrages* upon the Yonne are closed by wooden *hausses mobiles* 1.25 meters wide and 0.05 meter apart. During the season of low water the interstices are staunched by *couvre-joints*, *i. e.*, pieces of timber 0.25 meter to 0.30 meter wide, and 0.03 meter thick placed above against the *hausses*. The overfalls of fifteen of these *barrages*, when constructed, were furnished with the automatic *hausses* of Chanoine; these were 1.35 meters wide.

Automatic hausses.—The *hausses* of the pass have their axes of rotation higher up than those of the overfall and do not fall spontaneously, but by the aid of talon-bars moved by capstans; they are raised by a boat. The *hausses* of the overfall, on the contrary, were made to fall and rise themselves, on account of the position of the axes of rotation, which is 0.05 meter, above one-third the height of the *hausse*, and by the action of a suitable counterpoise. The ingenious system of automatic *hausses* for the overfall was at first highly esteemed on account of its simplicity and its success on a single *barrage*, as a means of disposing rapidly of the surplus water of a freshet without emptying the upper bay or interfering with the navigation of the stream; but great difficulties arose when it was tried in 1868, on a large scale, for the continuous navigation of the Seine and Yonne between Paris and Laroche. The floods of the *éclusées* from the Yonne, which were ponded above Laroche, or a little freshet, produced disturbances in the upper bays and overturned all the automatic *hausses;* that is to say, an elevation of water from 0.09 to 0.14 meter above the crown of the *hausses* was sufficient to overturn them. They did not shut again until the water had fallen 1 meter in the upper bay, thus stopping navigation and exposing the barges to grounding.

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* Plate XIV, Fig. 2.

† Plate XIII, B, Figs. 5, 6, 7.

Notwithstanding the zeal and devotion of the lock-men and employés o every grade, it was impossible to prevent this disorder as long as the *hausses* were not worked directly by the lock-men themselves; hence the engineers have not hesitated to propose the establishment of service-bridges above the overfalls with *hausses*;* this proposition was approved in 1868 and carried into effect in 1869 and 1870.

37. THE SERVICE-BRIDGE is composed of iron *fermettes*, like those of the needle *barrages* of Poirée, movable around a horizontal axle perpendicular to that of the overfall. Each *fermette* corresponds to the axis of a *hausse*. These *fermettes* are united at their tops by two connecting-bars, which limit the width of the walk; between these bars a flooring is placed 0.50 meter above the level of the water. The two connecting-bars are rails upon which the crab-engine rolls. Finally, to this crab-engine are attached two chains, one to the upper and one to the lower edge of each *hausse*. By the aid of the crab made fast to one or two *fermettes*, and with the two chains, every necessary manoeuvre is made without fatigue and without danger. In times of freshet, the connections between the *fermettes* are taken off in succession, commencing at one end. The first frame, relieved of all connections, revolves on the axis at its base and falls into a chamber in the platform on the bed of the river. The second frame is then disengaged and lowered over the first, and so on to the end; the height of the frames being greater than the interspaces, they lie partly over each other in the chamber prepared for their reception in the platform on the bed of the river, and in which they are below the level of the sill, and so protected from injury. The frames next the wing-walls fall into a recess in the masonry. The bars and the crab are stored. It is alleged that the *hausses* of the overfalls should not have counterpoises. These service-bridges have been also established at the two old overfalls of Pêchoir and Saint Martin, which have a special kind of gate movable around an axis fixed to the up-stream crown of the overfall.

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* Plates XIII, XIV.

38. The new system has been a perfect success. Each night the lockman is warned of the variation of the water in the upper bay by an alarm put in motion by a floater. In addition, all the *barrages* are united by telegraph, and the system, thus complete, prevents all surprise.

The experiments made in 1868 upon the working of the twenty-nine *barrages* constructed upon the Seine and Yonne has served as a basis for the new plans for improving the Yonne between Laroche and Auxerre. New *barrages* were planned with a movable pass closed by *hausses mobiles*, and an overfall with needles and *fermettes*. Six of the *barrages* between Laroche and Auxerre have this system of overfall.

LOCKS.

39. Dimensions, form, and mode of construction.—The three old locks have their walls vertical of solid masonry; the head-walls are 2.50 meters thick. Fifteen of the new locks have the heads, and masonry gate-chambers with vertical walls,* the rest of each lock-chamber is included between two walls, whose outer faces, sloping at an angle of 45°, are protected by stone pitching. They rest upon a mass of *béton* or masonry, reposing either upon a solid bottom or secured by rows of piles.

For the river-locks, the dike which forms the head-wall is 3 meters thick at the top, with an exterior side-slope of $\frac{2}{3}$, protected by stone pitching. The coping is masonry. The dike, constructed of earth, with a central core of rammed clay 2 meters thick, is generally very tight.

OVER-FALL AT BRULÉE ISLAND.

40. Girard's system of hydraulic-pressure sluice-gates.—The over-fall at Brulée Island is surmounted by a number of great sluice-gates, the invention of M. Girard, civil engineer. This system consists—

1st. Of a series of great wooden sluice-gates † attached to a horizontal rod, capable of turning in a cast-iron groove, firmly fixed to the crest of the masonry weir.‡

2d. Of hydraulic presses to raise the great gates, fixed upon the lower bay slope of the weir, and firmly anchored in the masonry.‡ The piston of each of these presses carries a cross-head§ of the strongest form, moving upon guides. This cross-head carries three connecting-rods,‖ which are joined to another cast-iron cross-head turning in a hollow cylinder¶ fixed in the center of the great gate.

3d. Of a series of copper tubes** to supply each press from the reservoirs or accumulators, where water is stored under pressure.

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* Plate XIII, A, Figs. 1, 2, B, Figs. 3, 4, show plans, elevation, and sections of the lock with vertical walls at Port à l'Anglais.

† Plate XII, A, Fig. 12.

‡ Plate XII, A, Fig. 13.

§ Plate XII, A, Figs. 1, 5.

‖ Plate XII, Fig. 1.

¶ Figs. 10, 11, 12.

** Figs. 13, 18.

4th. Of hydraulic works established upon the abutment of the over-fall.* These works consist of an upright turbine and two double-acting pumps, one for water and one for air, which are worked by the turbine and a reservoir of compressed air. The pumps and the reservoir communicate with each other, and with the presses by means of a three-way cock,† which allows the water to be forced into the reservoir, into the presses, or from either, into the discharge-pipe. The gates are moved by a single turning of the cocks. By putting each press into communication, either with the pumps, or with the water stored under pressure, an upward motion of the piston is produced, and the gate is raised. On opening, on the contrary, the discharging cock, the water escapes on account of the pressure of the gate, the press cylinder empties, the piston descends, and the gate falls. The reservoir of power regulates the working of the pumps; it serves, besides, to raise the *barrage* when there is no difference of level between the two bays, and consequently no fall to put the turbine in motion.

41. PRINCIPAL DIMENSIONS.—The over-fall of this *barrage* is 25 meters long, the sill is 2 meters below the level of the upper bay, and the fall is 1.85 meters. There are seven gates, each 3.52 meters wide and 1.97 meters high; when raised they have a declivity of 0.40; when lowered they are horizontal. There are also seven cast-iron presses; the exterior diameter of each is 0.40 meter, its thickness 0.04 meter. The cast-iron piston is covered with bronze, and has a leather cupped collar, thus forming a joint which becomes tighter as the pressure increases. The feed-pipes‡ lead into the bottom press cylinders; they are of copper 0.025 meters in diameter; they are placed in a little receptacle made in the masonry bed and connect with the cocks§. There is a tube for each press. In order to be secure from frost, the presses have been placed entirely below the upper bay,‖ as this arrangement renders them difficult of access for inspections and repairs; there have been established between each of them masonry partitions, furnished with slides,¶ by which, with the aid of joists, a coffer-dam can be established for each compartment separately; this can then be pumped dry, and the necessary repairs made.

42. The turbine has a vertical axis, and is 1.20 meters in diameter. It works by its upper crank,** *aa′*, a force-pump with a plunger, *pp′*, and an air-pump, *rr′*, situated on the same bed-plate. The two cylinders are shown in *bb′*. The influx takes place through the tube *c*, and the efflux through *dd′*. The valves†† are guided in their motions by a rod through a stuffing-box, and attached to a spring; by this arrangement the valve is forced back upon its seat when the piston comes to the end of its stroke, thus avoiding the shocks which would inevitably be produced if the valve was closed by the pressure of the water. The bronze piston is 0.08 meter in diameter, and has a stroke of 0.16 meter. The piston of the

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*Plate XI, Figs. 6, 8, 9, 10, 11, 12.

†Plate XII, Figs. 20, 22.

‡A, Fig. 13.

§A, Fig. 18.

‖C, Fig. IV, Plate XI.

¶C, Fig. V, Plate XI.

**Plate XII, Figs. 23, 24.

††Plate XII, Fig. 23.

single-barreled air-pump is upon the same piston-rod as the first pump. *e* is the induction tube, and *ff′* is the tube through which the air is forced. Two ball-clacks are used, and the cylinder may be emptied, or the forcing of air into the reservoir modified or stopped entirely, by opening the cock *g′*. *hh′* is a little air-receiver which regulates the working of the pumps when they are used to fill the presses directly without the intervention of the reservoir of force; it is furnished with a cock, *l′*. On the same figure the lubricating apparatus of the turbine is shown. The upright shaft *m′* of the turbine is hollow; it rotates around a spindle, *n′*, upon which its upper part rests at *k′*; an opening is made in this hollow shaft to pour oil into a cup placed here.

The pumps take the water directly from the river, when it is clean, or from a reservoir *a* made in the abutment.* The reservoir of force is a cast-iron cylinder † 0.66 meter in diameter and 3.50 meter in height; its thickness is 0.05 meter. The working-cocks are shown in Figs. 18 and 19. The tube *d* connects the reservoir of force with the distributing-tube *bb′*, upon which are situated the seven cocks corresponding with each of the presses. The tubes *a* connect the cocks with the presses; the discharge takes place through a tube, *cc′*, which throws the discharge-water into the reservoir in the abutment. C, Fig. 22, represents the three way-cocks placed upon the tube *dd′*, which allows the pumps, the reservoir of force, and the presses to communicate, as the figure indicates, or to connect the pumps with the *barrage* directly, or to shut off all three. The apparatus is furnished with both safety-valves and manometers not represented, which have been tested up to a pressure of 35 atmospheres.

The works are furnished with a sluice-gate,‡ and a grating§ serves to prevent the introduction of floating bodies. The dimensions of the different portions of the *barrage* were calculated by M. Girard, so that the pressure in the cylinders should never exceed 35 atmospheres. This pressure is required to raise the *barrage* under the full fall of 1.85 meters. The *barrage* of M. Girard is remarkable for its rapidity and ease of working, and it is wonderful to see these great gates rise against the current by the simple turn of a cock. We may, therefore, say that the trial which has been made at Brulée Island has been a perfect success, and it works wonderfully well. It takes less than a minute to raise a gate.

It will be possible, besides, to greatly diminish the pressure requisite to raise the gates by furnishing them with butterfly-valves,‖ which have already been tried upon two of them. These valves are placed on the upper part of the gate, the axle being at one-third of their height. When the gate is down they turn in the direction of the sheet of water which covers them; as they are of plate-iron they offer little resistance to the pressure of the water, so that the pressure upon the gate, when it begins to rise, is considerably diminished; when it emerges from the water the butterfly-valves close spontaneously. When the gates are raised a pressure of 7 or 8 atmospheres suffices to keep them up. It is not even necessary to keep the presses in communication with the reservoir of force; it is sufficient to shut off the water, and as the presses are tight they remain full.

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* Plate XI, Fig. 9.

† Plate XII, Fig. 21.

‡ Plate XI, Fig. 10.

§ Plate XI, Figs. 9 and 10.

‖ Plate XII, Figs. 9 and 12.

43. The expense of constructing this system of *barrage* is 50,000 francs, without counting the masonry. Its length is 25 meters, which makes 2,000 francs per running meter.

A needle *barrage* (*barrage à fermettes de Poirée*) in this part of the Yonne, where the foundations are easy of construction, would have cost 1,200 francs per running meter, everything included. The system of Girard has the advantage of easy working, but it has the disadvantage of being relatively very costly.

44. THE SEINE BETWEEN MONTEREAU AND PARIS.—The navigation upon the Seine before 1871 was, for three-fourths of the year, intermittent, but it has now been made continuous by the erection of twelve *barrages*. The descending tonnage amounts to 930,908 tons, while that ascending amounts to only 165,736.

A decree in 1868 provided for the establishment of twelve grand *barrages*, with locks which were to assure a minimum draught of 1.60 meters. These *barrages* have been constructed according to Chanoine's system; that is to say, *hausses mobiles* for the *passe*, and automatic *hausses* for the over-falls. The space between two consecutive *hausses* is 10 centimeters. At Melun alone there is a needle *barrage* for the overfall.

45. The navigable masonry *passes* are from 40 to 65 meters wide; their wooden sill, firmly fixed into the masonry bed, which is 10 meters wide, is 3 meters below the level of the upper bay, and 0.60 meter below the lowest level of the river. The new over-falls are from 60 to 70 meters in length; their sills are 0.50 centimeter below the lowest water; the masonry platform, 4 meters wide, is formed by a coffer-dam, filled with *béton*, surmounted with wooden cross-ties, the intervals of which are filled with masonry. Each over-fall is limited by a pier or abutment 3 meters wide. The lock-chambers are 12 meters by 180, so as to be able to take in twelve barges or four rafts. The heads of the locks and gate-chambers are of masonry, but the revetments of the lock-chambers are simply stone-pitchings of 45°; the head-dikes are of earth, with a central portion of clay; each dike is 3 meters thick at the top, and the slopes are protected by rough stone-pitching. The mitre sill is 1.60 meters below the level of the water in the lower bay. The trial in 1868, mentioned above in connection with the Yonne *barrages*, demonstrated the vice of the automatic *hausses* for over-falls, hence service-bridges have been established above all of them.

46. MODIFICATIONS OF THE LOCK AND BARRAGE AT PORT À L'ANGLAIS.—On account of the great distance, 24,600 meters, between

the two *barrages* at Port à l'Anglais and Surrennes, one situated above and the other below Paris, and in consequence of abandoning the idea of constructing a *barrage* in Paris itself, the depth of the lower bay, behind the lock at Port à l'Anglais, had to be increased 1 meter, and vertical walls had to be substituted for the sloping ones. In order not to interrupt the navigation during the reconstruction of this lock, which is on the left side,* a great breach was made on the right, in the over-fall, through which passed the traffic; this was afterward closed by a *pertuis*, (movable dam with *hausses.*) The old navigable pass, which had a width of 54.70 meters, has kept its *hausses* worked by a boat.† The over-fall, reduced to 37.90 meters, is separated from the *pertuis* by a pier 3 meters thick; the *hausses* of the over-fall are worked by a service-bridge.

47. NEW PASS OR "PERTUIS NAVIGABLE."—The new pass or navigable Pertuis of the *barrage* at Port à l'Anglais has a clear space of 28.70 meters between the piers. It is closed by twenty-six *hausses mobiles* of Chanoine's system. Its sill is 70 centimeters below that of the old pass, which is closed by *hausses* 3 meters high. The new movable gates rise to 3.70 meters above their sill. In order to support so great a head of water, changes had to be made in the models heretofore adopted by M. Chanoine for the *barrages à hausses mobiles.* They were as follows:

1st. The width of each *hausse* was reduced from 1.20 meters to 1 meter, with the same interval of 10 centimeters between each *hausse.* The wood-work has also been simplified; it is formed of two uprights‡ united by four ties. The uprights are 3.86 meters long and 0.30 meter by 0.20 meter section.§

2d. The inclination of the *hausse* to the vertical, which was 8° in the model of M. Chanoine, was made 20°, to diminish the effort tending to raise the sill from its bed.

3d. When a *hausse* is lowered it bears upon four cubes fixed into the platform bed; the gate is raised by two handles fixed to the uprights. By this arrangement the *hausse* is perfectly sustained, and no change of form in the wood is caused.

4th. In the primitive model of M. Chanoine, the axis of rotation is placed at five-twelfths of the total height. For the new *barrage* at Port à l'Anglais this arrangement would give to the *culasse*|| a height of 1.60 meters; 1.75 meters was given to it, and the axis of rotation was placed 15 centimeters below the center of figure.¶ This arrangement prevents these *hausses* from spontaneously falling, an inconvenience which was experienced in the older ones, causing the water to rise in the lower bay and reducing, unnecessarily, the fall. This inconvenience

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* Plate XIII, Figs. 1, 2.

† Plate XIII, Figs. 1, 2.

‡ Plate XIV, Fig. 6.

§ Plate XIV, Fig. 7.

|| The name *culasse* is given to that part of the upright *hausse* below the axis of rotation.

¶ Plate XIV, A, Fig. 6.

has actually been remedied by placing between the uprights little automatic valves, turning around a horizontal axis and having the dimensions of 100 by 42 centimeters.[*] These butterfly-valves, as they are called, open spontaneously before the *hausse* falls, and the lock-man shuts them at the proper time, with great ease, by means of a boat-hook from a boat passing along behind the *barrage.*

5th. Instead of being satisfied with a maneuvering boat to raise the great *hausses* of the new pass, there has been a service-bridge established above, composed of *fermettes*, of Poirée's system, upon which the lifting-crab rolls.[†] The *fermettes* of the bridge are 4.75 meters high, 3.10 meters wide at the base, and 1.20 meters at the top. Each *fermette* is placed exactly in front of the middle of each *hausse*, and the flooring of the bridge is 50 centimeters above the level of the bay. The uprights, the ties, and braces are formed of U iron, 8 centimeters wide, 35 millimeters high, and 7 millimeters thick.

48. The expense for lowering the lower bay of the lock at Port à l'Anglais:

	Francs.
The rebuilding of the revetment walls of the lock-chamber is	372,056.74
Cost of the navigable pass	225,000.00
Total	597,056.74
Previous cost	983,675.62
Total cost	1,580,732.36

COST.

49. (1.)—*Upon the Yonne, between Auxerre and Montereau.*—(Length of river improved, 108,277 meters.)

	Francs.
Seven *barrages* with locks from Auxerre to Laroche	2,219,000.00
Barrage of Gurgy, without locks	140,000.00
Eight *barrages*, with locks, from Laroche to Sens	3,696,000.00
Barrage of Joigny, without lock	170,000.00
Seven *barrages* from Sens to Montereau	3,927,000.00
Barrage of Courlon, without lock	200,000.00
12,715 meters of *dérivation* with great section	3,031,891.75
Miscellaneous work, dredging, improvement of tow-paths, examinations, wages, &c	3,440,188.51
Total expense from Auxerre to Montereau	16,924,080.26

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[*] Plate XIII, B, Fig. 5.

[†] Plate XIV, A, Figs. 1, 2, 8.

(2.) *Upon the Seine, between Montereau and Paris.*—(Length of the river improved, 98,000 meters.)

	Francs.
Five *barrages*, with locks, between Montereau and Melun	4,046,416.25
Six *barrages*, with locks, between Melun and Ablon	5,185,411.20
Barrage Port à l'Anglais	1,580,732.36
Various works, dredging, dikes, improvement of the tow-paths, studies, wages, &c	3,541,500.19
Total*	14,354,060.00

50. These works were planned and executed under the direction of M. Chanoine, and since 1867, under M. Cambuzat, both Chief Engineers *des Ponts et Chaussées.* Among the engineers who performed the work are MM. Legrené, Boulé, Remise, and last, but not least, M. Girard, the inventor, who was suddenly and prematurely removed from his most patient and ingenious researches.

51. MODE OF TRACTION, &C.—Formerly when the navigation was intermittent, by means of *éclusées* the descending boats followed the flood of the *éclusée.* They were towed back by steamers, hauling a submerged chain, which passed over the deck of the steamer, around cylinders put in motion by the engine. Above Montereau the boats are towed by horses. Since the establishment of the continuous navigation all modes of traction are tried, chain-towers, tow-boats, and ordinary towing.

52. The navigation being at its beginning the boats do not draw as much as they might. Old boats are still used, especially canal-boats. The mean load is 100 tons, the maximum load 200 tons for canal-boats and 350 for great river-boats. The freight consists of wood, wine, charcoal, grain, coal, and ores. We may estimate the tax on the freight at 3 centimes per ton per kilometer between Paris and Laroche, in either direction. On the Seine, above Montereau, and on the Yonne, above Laroche, at 4 centimes per ton per kilometer to descend, and 6 centimes to ascend. For firewood transported in rafts at 0.0155 franc per ton per kilometer, and 0.0246 franc by boats. Notwithstanding the difference in price, the transportation of firewood by rafts diminishes in favor of that by barges.

An indispensable complement to the improvement of the navigation of the Seine was the establishment of telegraphic lines, putting each *barrage* in communication with those above and below. This line has just been established.

53. VALUE OF NAVIGABLE ROUTES; CANALIZED RIVERS.—Before closing this chapter it may not be out of place to consider in a general manner the value of navigable routes in a country like ours, already covered by a network of railways; and the question arises whether this is not sufficient for all purposes of transportation. To answer this

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[*] The interest of the cost of these works, together with the annual expense of repair, represents, for the mean actual traffic, 2 centimes per ton per kilometer upon the Yonne, and 1 centime upon the Seine.

question let us compare the systems in a country in which both have been thoroughly elaborated. The system of internal navigation in France forms a vast network upon which we may go from one point to another by at least one continuous path. By means of canals prolonging the natural water-courses, or connecting them over the intervening elevations, the Seine, the Rhine, the Rhone, the Gironde, and the Loire communicate. Paris is the center of this network. This center is surrounded by means of the St. Dennis and St. Martin Canals, together with a portion of the River Seine, by a belt of water-line, from which diverge: 1. The western line, toward Havre; 2. The northern line, toward the ports of Calais, Gravelines, and Dunkirk; 3. The northeastern line, toward the Belgian frontier; 4. The southeastern line, toward Bale, on the Swiss frontier; 5. The southern line, toward the Mediterranean; 6. A southwestern line, toward the ports of Nantes and Brest. There is also a line from Bordeaux to Cette, thus joining the ocean with the Mediterranean.

These are divided by the administration, for the purpose of exacting tolls, into two classes, the one being treated and taxed as canals, and the other as improved rivers. In a technical point of view they may be divided into canals, canalized and non-canalized rivers. The length of the canals is about 3,000 miles; that of the canalized rivers is 2,000, and that of the uncanalized rivers 2,000, making a total of 7,000 miles of water-line against 10,000 miles of railway. With the exception of about 600 miles confided to private companies, all these are administered by the state, the reparation and construction being intrusted to the service of *ponts et chaussées*, (roads and bridges,) the navigation dues being collected by the administration.

CANALS.

The cost of these canals before the nineteenth century	116, 000, 000 frs.,	$23, 200, 000
During the present century	670, 000, 000 frs.,	134, 000, 000
Total	786, 000, 000 frs.,	157, 200, 000

CANALIZED RIVERS.*

The canalized rivers have a total length of 2,000 miles. The cost of the various improvements before the nineteenth century was 20,000,000 francs, or $4,000,000; during the nineteenth century, 230,000,000 francs, or $44,000,000.

NON-CANALIZED RIVERS.

Before the reign of Louis Philippe the uncanalized rivers had received no important improvement. In some parts simply dikes and defenses against inundations had been constructed. The cost of various improvements since 1831, such as the rectification of the banks, the closing of secondary branches, the establishment of low dikes to deepen the channel, etc., has been 147,485,000 francs, or nearly $30,000,000.

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* By a canalized river, is meant, one which has been rendered navigable by the erection of movable dams with side locks.

We may estimate the cost of the water-ways to be 1,200,000,000 francs, or $240,000,000; the annual cost of care and repair to be 9,000,000 francs, or $1,800,000, which we may estimate at an average of $500 per mile.

NAVIGATION-DUES.

The navigation-dues, since their reduction in 1867, have been $0.006 per ton, and per mile on rivers:

For first-class merchandise on rivers	$0.006
For second-class merchandise on rivers	0.003
For a cubic meter of wood (*stere*) in rafts per mile	0.0006

On canals for:

First-class merchandise	$0.015
Second-class merchandise	0.006
Stere of wood in rafts	0.006

These dues amounted in 1868 to 3,700,000 francs, or $700,000 for 1,050,000,000 tons transported one mile, (not including the tonnage on the non-canalized rivers.)

Coal is one of the most important articles of transportation. The boats may draw about 7 feet and carry 250 tons. The methods of towage are various, by men, by horses, and by steam-tugs; many of the latter are guided in their course (especially upon the rivers) by a submerged chain. This last method finds considerable favor.

The reduction of the navigation-dues has considerably reduced the price of transportation.

The freight on a ton of coal from Mons to Paris (about 222 miles) was 13.208 in 1847, *i. e.*, $2.64, while in 1866 it was only $1.28, this last figure corresponding to the exceedingly low price of .570 of a cent per mile. We must regard this price as singularly small when we consider that the boats have little freight to carry back.

We may regard the minimum price as five-eighths of a cent. per ton per mile, and the maximum from one to one and one-half cents.

COMPARISON OF WATERWAYS WITH RAILWAYS.

When we may choose between a water-line and a railway between two given points, the latter is usually less sinuous than the former, and we may admit that 1,000 feet by water are equivalent to 800 feet by rail.

Under these conditions the average price of a ton of merchandise by the two ways is as two to three—in other words, the railway augments 50 per cent. the price of transportation, but it offers in return the advantage of speed. In 1869 the freight on a ton of coal from Mons to Paris was $1.28 by water and $1.84 by rail. These prices are about in the ratio of 2 to 3 as indicated above.

The freight is about equally divided between the railway and the waterway, and we may say, as far as commerce goes, these two are equivalent, each having its advantages and its disadvantages.

Upon the most prosperous portion of the system of inland navigation, especially in the North, the activity of freight by water is comparable with that upon the railways; it has been increasing for the last twenty years, and has effectually contested the monopoly of the railways, and thus contributed largely to diminish the cost of transportation.

Finally, if we suppose the difference in the cost of transportation of one ton one mile to be one-third of a cent, applied to the 1,500,000,000 of mile tons which annually pass through the French rivers, this difference would annually amount to $5,000,000, an economy in the reduction of the price of articles of first necessity.

We must hence conclude that navigable waterways are indispensable, not only where the means of transportation are scarcely developed, but also in one which is largely served by a complete network of roads and railways.

The total tonnage on the railways is 4,000,000,000 mile tons.

These facts would have little value were it not that within a few years the improvements above mentioned have taken place in the construction of movable dams and river-gates, so as to permit, easily and with comparatively little expense, rivers heretofore not navigable to be converted into canals.

54. AWARD.—The jury for Group XVIII awarded to MM. Cambuzat and Boulé Medals for Progress; to MM. Girard and Nicolle Medals of Merit.*

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*I am indebted to Messrs. Cambuzat, Boulé, Remise, Lucas, Legrené, and Malézieux, Professor at the School of Roads and Bridges, for valuable information and drawings.

CHAPTER VI.

DESCRIPTION OF THE SYSTEM ADOPTED FOR FEEDING THE CANAL BETWEEN THE RIVERS AISNE AND MARNE.

Situation of the canal; Strata through which it is cut; Description of Des Fontaine's drum barrage; Canal for supplying the motive-power; Establishment at Condé; Sluice-gates; Pent-stock and tail-race; Waste-channel; Turbines and pumps; System of valves; Side channel; Efficiency of the pumps and turbines determined by experiment and by calculation; Cost; Comparison of the cost of raising 1,000 cubic meters of water to a height of one meter by this system with that by other systems in use; Medal awarded.

(Plates XV, XVI.)

55. The feeding of the canal connecting the rivers Aisne and Marne presented serious difficulties. This important route, connecting directly the canals of Eastern France with those of Belgium and the North, traverses the undulating plain of the Champagne. Having been opened in a stratum of permeable white chalk, the canal had to be stanched throughout its whole extent. Again the resources for the supply of feed-water were very scanty; not that this region was deficient in water as was believed after a superficial examination; on the contrary, abundance was found in the lower valley, and numerous observations tended to prove the existence of an immense sheet of running water under the permeable stratum. But this water was altogether too low to feed the canal.

56. For this purpose the Vesle, a little stream supplying the city of Rheims with water, and also working the numerous factories in the neighborhood, was tapped, and, until 1869, was the only means of feeding the canal. Consequently the summer waters of the Vesle, which barely sufficed for the use of the city and factories, left the canal dry for one-third and sometimes for one-half of the year. In order to supply the requisite feed-water, about 600 liters per second, the only admissible resource was to take this water from the Marne, which could be accomplished in two ways:

1st. By a supplementary canal, or derivation from the upper Marne or one of its branches, bringing the required amount of water, with a gentle slope, to the upper bay, at the summit level on the canal.

2d. By a system of pumping-engines, taking the water from the Marne and forcing it up to the level of the same upper bay by a short conduit.

The first project was inadmissible on account of the slight declivity of the valley of the Marne, and the great number of valleys to be traversed, by side-channel or *rigole*. This *rigole* would have been as long as the derivation itself, and since it had to be cut through the same strata, it would require stanching throughout its whole extent. The second method was consequently adopted, using water-wheels as motors instead of steam-engines. The results obtained have entirely justified the choice. The order was given on the 7th of August, 1867, and the machines began to work in 1869. They are now in full activity and can furnish to the upper bay of the summit level a volume of 1,200 liters per second; thus assuring a continuous navigation in a canal whose annual tonnage amounts to more than 400,000 tons.

57. The system adopted consists of three portions:

1st. The canal to bring from the Marne the water to move the hydraulic machines.

2d. The establishment containing hydraulic motors and the pumps.*

3d. The conduit and its duct up to the point of the introduction of the feed-water.

We shall examine each of these parts in detail.

58. THE SUPPLY-CHANNEL.—The water to move the machines is taken from the Marne at Chalons. A drum *barrage*, constructed according to Desfontaine's system, throws part of the water of the river into the old canal of the city, which forms the head of the feeding-canal.

[*Note on the drum barrage.*—Mr. Desfontaines, late chief engineer of the navigation of the Marne, has constructed upon this river a number of *barrages* of his own invention. Each of these consists of a system of *hausses* of a height a little more than double the difference of level in the upper and lower bays, and movable around an axle, *a*, (Fig. 16,) placed in the middle. They are curved below the axle and have the form *a b e*. The axle is fixed to the upper lip of a cast-iron box. This box is partly open to allow the motion of the *hausse*, and has the contour *a e f g h*, with a curved portion from *f* to *d*, which stops at *d*, thus allowing the *hausse* to move from the position *b a c d* to the position *b′ a c′ d′*, leaving the two orifices, *l* and *k*, outside of its path. The upper part of the box is flat, one portion below the other, so that the *hausse*, when lowered into the position *a b′*, is a little below the level *a e*, and thus hidden by it.

Each *hausse* is fitted to a special box or drum, but all the boxes are pierced with oblong holes, *l* and *k*, so that they communicate when arranged side by side. The drums are fitted together by flanges around these holes, thus affording a communication along the whole line of the *barrage*, both before and behind the *hausses*, with the water in the upper bay.

It is now evident that if, by means of sluice-gates or valves, the tube *l* is put in communication with the upper bay and the tube *k* with the lower bay, the difference of pressure on the face of the *hausse* will cause it to rise and take the position *b a c d*. If, on the other hand, the tube *k* is by a second system of sluice-gates put in communication with the upper bay and *l* with the lower bay, the system is reversed and the pressure forces the *hausse* to take the position *b′ a c′ d′; i. e.*, lowers the *hausse*.

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* Plate XVI.

The simple turning of a valve thus opens the whole *barrage*. The time for opening is one and a half minutes; the time for closing four and a half minutes.

Fig. 16 shows the cross-section of the *barrage* with the *hausse* raised.

Figs. 15 and 15 A represent the plan and elevation of a *hausse* with its drum.

This *barrage* is not a movable one; it is fixed and only adapted for over-falls for which it is intended.*]

This canal has a total length of 18,368 meters, of which 14,146 have recently been constructed. The fall is 10 centimeters per kilometer. The cross-section is a trapezoid 8 meters wide at the bottom, the sides having a slope of 3 base to 2 of height.

The formula of M. Bazin for the uniform motion of water in canals, shows that such a canal, with such a fall and cross-section, can give a flow of 13,600 cubic meters per second, when the water attains a depth of 2.20 meters; but as the banks are raised throughout 2.60 meters above the bottom of the canal, this volume of water can be considerably augmented. The sides of the canal have been protected in the portions especially exposed to the action of the current. In addition the canal has been rendered impermeable by covering the bottom with layers of pulverized chalk, and then rolling it like a macadamized road.

The canal† supplying the works of Condé is a prolongation of the St. Martin Canal. It has its origin at St. Martin's le Pré, and extends for a considerable distance along the lateral canal of the Marne; it diverges at Joigny and passes near the villages of Vraux and Aigny, and finally flows into the basin at Condé, upon the left slope of the valley of Isse, which forms the connection between the canal of the Aisne and the Marne. The level in the basin of the works at Condé is 71.54 meters above the level of the sea, and the highest level yet attained by the waters during a heavy freshet is 75.34 meters. Thus the canal of supply affords a fall of 6.92 meters for the low summer waters, and one of 3.12 for heavy freshets.

The water in the basin is divided into three parts. The first is used to drive the machines; the second is raised by the pumps and forced up to the summit level of the canal through the ascending conduit; the third is the waste-water which passes over the "overflow" and unites in the tail-race with the first portion issuing from the machines. This

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* I wish in this connection to express my indebtedness to M. Jozon, Engineer *des Ponts et Chaussées*, stationed at Chateau Therry, for a visit to the drum *barrages* on the Marne, and for the opportunities of seeing them in operation as well as for numerous other courtesies extended.

† Plate XV, map.

Fig.12

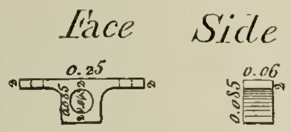
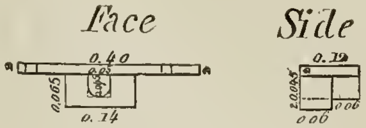


Fig.13



Front and side elevations of the up-stream and down-stream gudgeons.

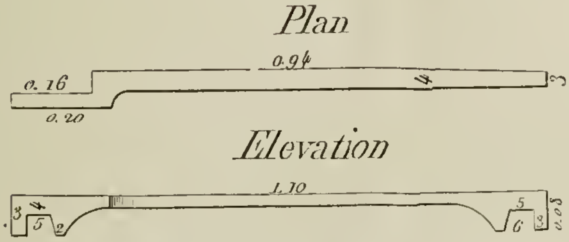


FIG. 14.—Plan and elevation of the bar uniting two adjacent *fermetes.*

DESFONTAINE'S DRUM-BARRAGE.—Art. 58.

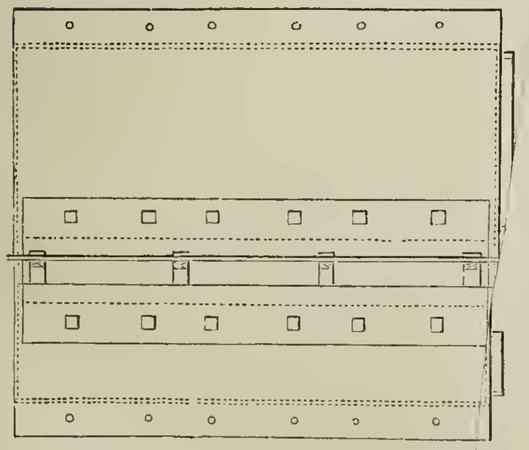


FIG. 15.—Plan of the *hausse* and its drum.

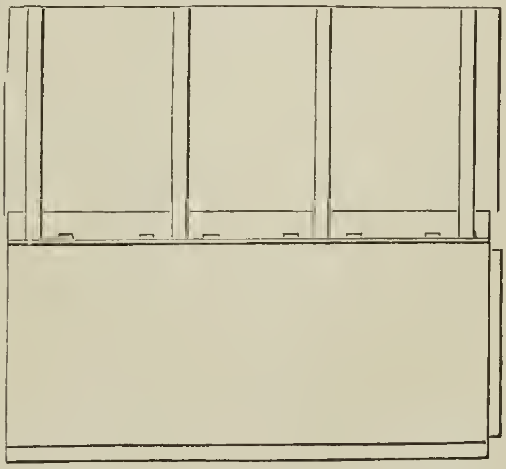
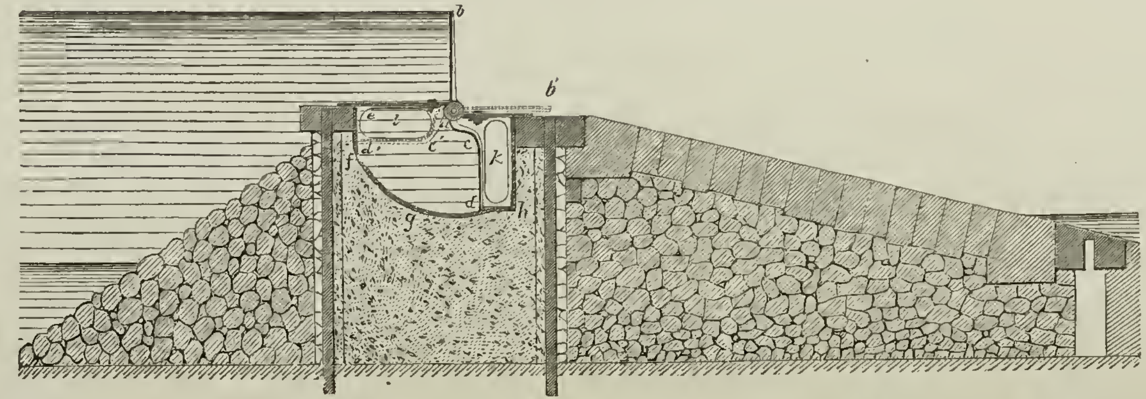


FIG. 15 A.—Elevation of the same.

DESFONTAINE'S DRUM-BARRAGE.—Art. 58.

FIG. 16.—Transverse section.



EXPLANATION.—*a* is the axle; *a e f g* the drum; *a b* a *hausse* or gate; *a c d* a counter-*hausse;* *b a c d* is the gate raised; *b′ a c′ d′* is the gate lowered; *k* and *l* are transverse iron canals extending the whole width of the dam; *k* communicates with the lower and *l* with the upper bay, or *vice versa* according as the gate is to be raised or lowered. This communication is made by aqueducts and sluice-gates placed in the pass and abutments of the dam.

tail-race passes under the lateral canal and discharges into the Marne itself.

All necessary precautions have been taken to preserve the walls against the destructive effect of the whirlpools. The arch of the aqueduct under the lateral canal was arranged so as to resist the pressure to which it would be exposed during freshets.

59. SLUICE-GATES.—The apparatus for regulating the water in the supply-canal consists of a certain number of gates which exclude at will a greater or less quantity of water. The gates are of cast iron, which was preferred since it best resisted the chemical action of the water; those of wrought iron would have been rapidly oxidized in the river. These gates are moved by iron screws working in bronze nuts, an arrangement which allows the workman to stop at will, without needing other apparatus to prevent the gate from falling. The working of the gate is somewhat slow, but even this is an advantage rather than a defect, for it avoids the destructive scouring which is often caused by the sudden influx of a great mass of water. On account of this slow motion, the effort necessary to raise the gate is very little, and never exceeds the strength of one man.

The level of the water* at the works is regulated by an overflow formed by two parallel lines of cast-iron upright plates, uniting in a circle at their extremities and braced so as to mutually support each other. The water which flows over this kind of box passes through three vertical pipes, each a meter in diameter, into a sort of pit, where it loses its velocity in eddies, and whence it is conveyed, by a lateral overflow 16 meters wide, into the tail-race, without the slightest fear of its wearing away the banks of this last open channel. The plates of the upper overflow have four openings which are opened or closed at will by gates, and which serve in ordinary times for the discharge of the waste. The upper overflow is only used in times of freshets, when the orifices of discharge are not sufficient. As soon as the level of the water rises 7 centimeters above its ordinary height, the volume of water which passes through the orifices and over the top of the overflow equals the maximum flow of the canal, viz, 13.17 cubic meters per second. In virtue of this surface overflow, which regulates itself without the intervention of mechanism, we may regard the level of the basin as nearly invariable, and not dependent upon the vigilance or fidelity of the employés.

60. WORKS AT CONDÉ SUR MARNE.—These works include the motors and the pumps.† The motors consist of five Koechlin turbines placed in a line, having their vertical axes 10 meters apart. They set in motion, by means of bevel gearing, a series of horizontal shafts coupled together in a line.

There are six double-acting vertical pumps, the pistons of which are moved by a horizontal shaft by means of cranks and connecting-rods.

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* Plate XVI, Fig. 1.

† Plate XVI, Figs. 1, 2.

They are situated entirely above the water which they have to raise. The six pumps are divided into three groups of two, placed alternately to the right and left of the three central turbines, so that each of these turbines moves the two neighboring pumps. The different portions of the main shaft may be coupled or uncoupled; for this purpose the couplings are put between the crank-pins of the cranks, which move the two neighboring pumps. Thus the three central turbines can work independently, like three separate machines; or they may be coupled together, taking care to place the six cranks at the proper angles. As to the two end turbines, they are auxiliary machines, and are coupled with the three central turbines when the fall is least; *i. e.*, at the time of a freshet in the Marne. As the motive-power diminishes in proportion to the reduction of fall, a corresponding compensation is obtained by surplus on employing two additional turbines, which utilize the additional volume of water.

61. The choice of the turbine as the motor was made imperative on account of the great variations of fall. Among the known types has been selected Koechlin's turbine, which has the advantage of accommodating itself to the regulation of the volume of water admitted into the machine, and also of allowing the movable crown to be placed in such a position as to be easily inspected and repaired. The turbines employed at Condé have a diameter of 2 meters; the height of the crowns, originally 30, has been reduced to 20 centimeters, thus bringing the dimensions of the turbines to those best adapted to the work required.

The gate of the Koechlin turbine is cylindrical and is placed at the base of its fixed pipe. This gate, which may be raised more or less, according to the flow, acts as a regulator, or rather as a brake, when the flow begins to diminish. Each turbine is fed by a water-tank or chamber, which may be completely shut off from the rest of the works, by means of gates; when these are shut and the tank emptied, the turbine can be inspected and repaired. The walls of the tanks are of cast iron, and thus form a solid and rigid structure between each turbine and the two adjoining pumps. Thus a little inequality in the settling of the foundations of the works will have no effect upon each turbine and its transmission of power. Its only effect will be to slightly modify the height or the inclination of some of the elements of the transmission. Such an alteration affects in a degree the connection which may be established between the five machines to make them work together. Then again, by adjusting the connecting pieces of the different portions of the shaft, allowance is made for the slight displacements which may take place.

The uniform rotation* of the vertical axle of each turbine is transmitted to the horizontal shaft by a wrought-iron pinion and a cast-iron bevel-wheel. The pinion is 0.628 meter in diameter; the wheel serves as a fly-wheel and also to transmit the power; its diameter is 5.984 meters. Each portion of the shaft is terminated by two cranks at right angles, each 50 centimeters in length to the center of the crank-pin; to this pin is attached the connecting-rod of one of the pumps; this rod is 2.50 meters long, and is attached at the other end to the piston-rod of a pump. The interior diameter of each pump-barrel is 0.95 meter; in it moves a hollow, cast-iron piston, 0.93 meter in diameter; the piston is packed by a double leather collar, which the pressure of the water forces against the interior surface of the barrel; one of these collars serves for the ascending, and the other for the descending, stroke. To diminish the wear of these leathers the engineer in charge has put in a bronze circle, having a T-shaped section; by this improvement the leather, it is thought, may be made to last a year or more.

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*Fig. 3.

Valves.—The arrangement of the valves is the most important improvement of these machines. None of the systems of valves hitherto in use were found applicable here. Almost all spindle-valves are exposed to shocks of a greater or less violence; applied to the pumps at Condé, they would have been too large and too heavy. The solution, definitely adopted, was to employ for valves large, rectangular clacks, fixed to a turning-shaft and capable of entirely opening the supply and discharge-pipes, and offering no obstruction to the flow. This turning valve-shaft, prolonged outside the conducting-pipes, is acted upon by a spiral spring, which, united by bell-cranks (Fig. 5) and an eccentric to the main shaft, closes the clacks gradually, when the piston, completing its stroke, reverses its direction. The clack, once shut, opens again by the effort of the spring in a contrary direction, as soon as the backward direction of the piston has developed pressure enough to counterbalance the pressure of the outside water.

By this mechanism, the idea of which is taken from the valves of a steam-engine, the clacks close slowly and without noise, and open, on the contrary, with great rapidity. As water is nearly incompressible, there have been reserved at the center of each great clack a certain number of smaller clacks, 4 centimeters wide by 16 high, the motions of which are free. The rising of these little valves suffices to give vent to the small portion of liquid when the piston comes to the end of its stroke, and the principal valve falling upon its seat interrupts suddenly the motion of the liquid vein. A single eccentric regulates the motions of the four clacks of a pump. The valve-gear is so perfect that no shock is heard as long as there are not more than nine strokes per minute. Observations made with Watt's indicator show that each clack rises suddenly and remains stationary during ninety-three hundredths of the stroke, and then falls gradually upon its seat. That this gradual motion is caused by the springs is proved by removing them, in which case the motions of the clacks are sudden, accompanied with great noise, thus showing to what shocks they are subjected.

62. *Pumps.*—The pumps are double acting, but the pipes, corresponding to one of the faces of the piston, can be closed by valves, and the

work of the machine reduced one-half. The loss of power by the alternate compression and expansion of the volume of air inclosed in the cylinder is so small, that it can be neglected, while it doubles the ease of working. The water from the pumps* is forced through a special pipe into a great pipe 1.10 millimeters in diameter, which forms the base of the ascending pipe. This great tube is surmounted by three air-receivers 5.20 meters high and 1.10 meters in diameter, each containing about 14 cubic meters of air. The intervention of this elastic medium regulates the pressure of the water in the ascending conduit, and avoids the severe shocks which would otherwise be repeated at each stroke.

63. *Conduit.*—The rising conduit follows the pipe of 1.10 meters diameter. It consists of two lines of pipes 0.80 meter in diameter. These may be shut off at will by valves, so that they may be separately emptied, and every 100 meters there is an arrangement for examination. Each tube is 4 meters long. The joints are like those of street water-pipes. The total length of the conduit is 621 meters. It discharges into a masonry tower where the water rises to a height of 97.55 meters above the sea-level. This tower is at the head of the supply-channel which is carried at first upon a series of masonry arcades, each having a span of 3 meters. Soon, however, it reaches the level of the soil, which it follows to the summit level in the valley of the Isse, with a uniform fall of 15 centimeters per kilometer. Its cross-section is a trapezoid 2.20 meters wide at the bottom, 2.40 meters at the top, and 1.25 meters deep. The bottom is entirely of *béton.* The sides are little stone-walls, and at intervals above the channel small arches are placed, whose thrust serves to prevent the walls from approaching each other. The supply-channel, 7,605 meters long, can furnish 1,237 liters per second when the level attains a height of 1.10 meters.

64. *Efficiency.*—It remains for us now to consider the efficiency of the works, the cost of construction and the annual expenses.

The volume of water, which is raised to a height of 19.09 meters, varies from 600 to 1,200 liters per second. Taking account of the resistances in the pipes, we perceive that the useful work must vary from 12,132 to 28,668 kilogrammeters.

The efficiency of the pumps has been determined by a series of trials to be about 95 per cent., *i. e.*, the ratio of the volume swept through by the piston to the volume of water raised; the 5 per cent. loss is attributable to the presence of air in the valve-spaces of the clacks. This loss might be lessened by the aid of air-cocks, but its presence is without sensible influence upon the efficiency of the turbines, since by its expansion it restores the work done by its compression.

The efficiency of the turbine is the most important consideration, and it may be determined by observation or by calculation. It varies accordingly as the gate situated at the base of the turbine is more or less raised. When raised 5 centimeters, the calculated efficiency was 0.40, the observed efficiency 0.39. When the gate was entirely raised the calculated efficiency was 0.664, and the observed efficiency was 0.67. Experience thus confirms the theory that the turbine works to the best advantage with the full gate.

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*Fig. 5.

It may be interesting to the readers of this report to have some of the details of the comparison between the observed and the calculated efficiency of the system and see how well practice agrees with theory.

65. The experiments made upon the machines at Condé were to determine—

1. The ratio of the volume of water raised and that swept through by the pump-plungers.

2. The volumes of water used by the turbines for different heads and for various heights of gate.

3. The efficiency of the system.

The first series of experiments to estimate the efficiency of the pumps was made by means of a weir placed in the *rigole;* over the crest of this, the water raised had to flow. The volume raised in 30 minutes was 696,300 liters; the number of revolutions was 256; for each revolution the pistons swept through 700 liters four times, (*i. e.*, 4 cylinders,) making a total of 716,800 liters; which gives the ratio 0.971; other experiments gave 0.948, and the mean of a series gave 0.951.

This loss of 5 per cent. is due to the presence of air in the valve-spaces, as has been shown by calculation. In the following table simultaneous experiments were made to determine the efficiency of the system:

Hour observed.	Height of the lower gate.	Fall to the entering orifice.	Flow from the orifice.	Volume of water used, Q.	Fall, H.	Water raised, q.	Real height.	Effective height.	Work of the motor, $\pi Q H$.	Useful work in water.	Efficiency.
h. m.	*Meters.*	*Meters.*	*Liters.*	*Liters.*	*Meters.*	*Liters.*	*Meters.*	*Meters.*	*Kmtrs.*	*Kmtrs.*	
8.15......	0. 054	0. 130	1, 789	1, 593	6. 12	196	19. 56	19. 68	9, 749	3, 857	0. 39
8.30......	0. 072	0. 150	1, 921	1, 657	6. 10	264	19. 69	19. 91	10, 107	5, 256	0. 52
8.45......	0. 090	0. 170	2, 045	1, 738	6. 08	307	19. 61	19. 91	10, 567	6, 112	0. 57
9.00......	0. 108	0. 185	2, 134	1, 806	6. 07	328	19. 65	19. 98	10, 962	6, 553	0. 59
9.15......	0. 126	0. 192	2, 174	1, 826	6. 065	348	19. 68	20. 06	11, 075	6, 981	0. 63
9.30......	0. 180	0. 205	2, 246	1, 878	6. 05	368	19. 68	20. 10	11, 362	7, 397	0. 65
9.45......	0. 360	0. 213	2, 289	1, 904	6. 04	385	19. 74	20. 19	11, 500	7, 773	0. 67
10.00......	0. 414	0. 215	2, 300	1, 913	6. 035	387	19. 74	20. 20	11, 545	7, 817	0. 67

π Denotes the weight of cubic meter of water.

66. *Theoretical calculation of the efficiency of the system.*—We shall first consider the loss of power due to the various prejudicial resistances. These are:

1st. Loss of living force of the water in passing through the valves and into the pump-barrel.

2d. Friction of the piston in the cylinder.

3d. Friction of the piston-rod in the stuffing-box.

4th. Friction of the cross-head in its guides.

5th. Friction of the crank-pin.
6th. Friction of the horizontal shaft in its bearings.
7th. Friction of the cogs in the mechanism for transmission.
8th. Friction of the turbine-spindle on its pivot and in its bearings.
9th. Work expended to move the clacks.

Without giving the details of the calculations, the results obtained are, for one revolution, as follows:

	Kilogrammeters.
1st. Loss of *vis viva* of the water	167
Friction of the piston	1,728
Friction of the piston-rod	70
Friction of the cross-head	320
Friction of the crank-pins	1,342
Friction of the shaft	1,779
Friction of the turbine-spindle	1,019
Work to move the valves	75
Total	6,500

The loss of power due to the friction of the cogs in the mechanism of transmission is $\frac{1}{100}$ of the total work transmitted.

Now the effective height for the water to be raised is 20 meters; deducting 5 per cent. from the volume generated by the pistons, the work for one revolution will be $.95 \times 4 \times 700 \times 20 = 53{,}200$ kilogrammeters. The work absorbed by the prejudicial resistances is 6,500 kilogrammeters, *i. e.*, 12 per cent. of the water lifted, to which must be added the per cent. absorbed by the friction of the cogs, making the work consumed by the prejudicial resistances 0.13 of the total work.

If W_u represents the useful work and W_t the total work, we shall have

$$W_t = W_u \times 1.13, \text{ hence } W_u = W_t \times 0.885.$$

Let us now take the equations which regulate the working of a Koechlin's turbine; they are as follows:

$$Q = w_1 \, \omega_1$$

$$\frac{Pv}{\pi Q} = \frac{2v \, (u \cos a_0 + w_1 \cos \gamma_1 - v}{2g} - \frac{w_1^2}{2g} F_1$$

$$H = \frac{w^2}{2g} \Bigg\{ \left(\frac{\omega_1}{O}\right) \left(\frac{1}{\mu} - 1\right)^2 + \left(\frac{\omega_1}{O_0}\right)^2 + \left(\frac{\omega_1}{\omega_0}\right)^2 - 1$$

$$+ \left(\frac{\omega_1}{O_2}\right)^2 + \left(\frac{\omega_1}{S}\right)^2 + f_1 + f_2 - 2\frac{\omega_1}{O_2} \sin \gamma_1 - F_1 + F_2$$

$$+ 2\frac{v \, \omega_1}{w_1 O_0} \left[\cos a_0 - \sin (a_0 + \gamma_0) - \cos (a_0 + \gamma_0) \right] \Bigg\}$$

$$F_1 = -\,0.0092\,\frac{v}{w_1} + 0.01212\,\left(\frac{v}{w_1}\right)^2$$

$$F_2 - F_1 = 0.0510 - 0.0561\,\frac{v}{w_1}$$

Q = volume of water used per second.
π = weight of a cubic meter of water.
O = upper orifice of the fixed crown.
O_0 = the sum of the exit orifices of the fixed crown.
O_2 = the section of the great pipe under the movable crown.
S = the contracted orifice of the exit of the water from the lower buckets.
H = height of fall.
ω_0 = sum of entrance orifices of the movable crown.
ω_1 = sum of exit orifices of the movable crown.
v = the velocity of the mean radius.
u = absolute velocity of the entering water.
a_0 = angle of this velocity with the circle of rotation.
γ_0 = supplementary angle of the bucket with this circle.
w_0 = relative velocity at this point.
a_1, γ_1, w_1 = same quantities for the exit from the movable crown.
f_1, f_2 = are constants of friction.

Substituting the values of the dimensions of the turbines adopted at Condé, we have

$$(1)\,\frac{P\,v}{\pi\,Q\,H} = \frac{2\,\frac{v}{w'}\left(1.997 - 102\,\frac{v}{w'}\right)}{2.50 + 0.064\,\frac{v}{w_1} + \left(\frac{\omega_1}{S}\right)^2}$$

$$(2)\ H = \frac{w_1^{\,2}}{2g}\left[2.50 + 0.064\,\frac{v}{w_1} + \left(\frac{\omega_1}{S}\right)^2\right]$$

$Q = 0.27\,w'$ $\qquad$ $S = 4.56\,Z$
$f_1 = 0.08$
$f_2 = 0.04$

Z is the height of the gate; we have also the relation between the velocity of flow from the orifices of the turbine and the number of revolutions per minute N, viz: $v = 0.897\,N$.

We can now, with the aid of the foregoing formulæ, calculate the values Q, w', and the efficiency $\frac{P\,v}{\pi\,Q\,H}$, $P\,v$ denoting the energy of the wheel.

The following table gives the results with a comparison with those furnished by experiment:

Hours of observation.	Height of the gate.	Fall H.	Volume Q.		No. of revolutions, N.	Calculated efficiency.	Efficiency of the system by—	
			Calculation.	Experiment.			Calculation.	Experiment.
Hrs. min.			*iters.*	*Liters.*				
8 15	0. 054	6. 12	1, 512	1, 593	4. 4	0. 46	0. 407	0. 39
8 30	0. 072	6. 10	1, 636	1, 657	6. 1	0. 60	0. 531	0. 52
8 45	0. 090	6. 08	1, 704	1, 738	7. 0	0. 65	0. 577	0. 57
9 00	0. 108	6. 07	1, 736	1, 806	7. 5	0. 68	0. 602	0. 59
9 15	0. 126	6. 065	1, 769	1, 826	7. 7	0. 70	0. 619	0. 63
9 30	0. 180	6. 05	1, 798	1, 878	8. 3	0. 71	0. 628	0. 65
9 45	0. 360	6. 04	1, 825	1, 904	8. 7	0. 73	0. 646	0. 67
10 00	0. 414	6. 035	1, 831	1, 913	8. 7	0. 75	0. 664	0. 67

The results given by calculation differ very little from those given by experiment, and in every case they follow the same law, thus verifying the formulæ given above. The differences must be attributed to the coefficients used and errors in gauging. The influence of the gate, which acts as a brake upon the efficiency of the system, shows the wisdom of adopting five turbines instead of one. This arrangement allows us to vary, between considerable limits, the amount of water used, without being obliged to have the gates partly shut, thereby losing considerable by the contraction of the fluid vein. As heretofore stated, the works accommodate themselves to all variations, both of head and volume of water utilized, without loss of efficiency.

The coupling of the portions of the main shaft, and the facility for converting some of the pumps from double to single action, serve to give the system that elasticity of working which is one of its most valuable qualities.

67. THE COST OF THE ESTABLISHMENT:

	Francs.
General expenses	25, 847. 87
Land and damages	368, 190. 06
Supply-canal	777, 282. 47
Tail-race, overflow, and buildings, &c	350, 360. 31
Approaches, &c	68, 621. 75
Rising conduit	130, 248. 45
Side-feeding-channel	333, 557. 07
Pumping-engines, turbines, &c	483, 092. 72
Total	2, 537, 200. 70

Annual expenses:

Salaries	9, 300. 00
Care of machines, etc	10, 700. 00
Total	20, 000. 00

The following table serves to show the expense of raising 1,000 cubic meters per day, one meter in height, for the water-works at Condé, and by various other systems of pumps worked by water-wheels or steam-engines:

Services.	Mean volume raised per day.	Mean height.	Cost per 1,000 cubic meters, raised one meter.
WORKS MOVED BY WATER-POWER.			
	Cubic meters.	*Meters.*	*Francs.*
Works at Condé sur Marne	50, 523	20. 22	0. 0534
Works at Saint Maur, (two Fourneyron and four Girard turbines)	43, 866	59. 65	0. 067
Works at the Iles-des-Meldeuses, (two Girard turbines)	24, 896	11. 73	0. 109
Works at Trilbardou, (two breast-wheels)	18, 526	14. 92	0. 212
WORKS MOVED BY STEAM-ENGINES.			
Works at Landrecies, Archimedean screw, worked by a steam-engine of 20-horse power	20, 488	1. 85	1. 150
Works at Chaillot, Paris, (steam-engine, 200-horse power)	25, 372	50. 43	0. 613

68. The works at Condé sur Marne were designed and executed by M. Gérardin,* engineer of roads and bridges. The machines were erected by M. Claparède. Both these gentlemen received the well-deserved Medal of Merit.

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* I am indebted to M. Gérardin, now professor in the National School of Roads and Bridges, for drawings and information in reference to this new and important work.

CHAPTER VII.

DESCRIPTION OF THE NEW STEAM PILE-DRIVER USED AT GRAVELINES.

Time and cost of driving piles; Cost of the machine; Medal awarded.

(Plate XVII.)

69. Among the works executed for the port of Gravelines were the two wooden jetties, having an aggregate length of 383 meters. The eastern jetty, 150 meters long, was founded upon a double line of elm piles, 30 centimeters square, and driven in 4.50 meters. These piles were spaced engthwise 2 meters, and crosswise 5 meters. There were consequently 300 piles driven, in two parallel files, into the old dike. The surface of this dike, destroyed by the sea, afforded no place to set up the pile-drivers. In addition, there was a scarcity of workmen in the vicinity. Influenced by these considerations, it was determined to employ the steam pile-drivers* already in use at the port. It became indispensable, however, to make certain changes, so as to put the motor out of the reach of the waves, to give the apparatus sufficient stability, and at the same time to insure a proper freedom of motion. As the piles were uniformly spaced, it was possible to use two pile-drivers coupled together and driven by a single steam-engine.

70. Description of the apparatus.—The apparatus consists of three parts, the base, the face, and the trestle-platform, called "*chevalet*" or horsing-frame. The base is formed of elm timbers, 30 centimeters square, making a frame 4.80 meters wide and 7.80 meters long, firmly joined and strengthened at the angles by strong ties. At the bottom of the frame, two iron plates are fixed, upon which are fastened the rollers; upon these rollers the whole is moved by a crab-engine placed on the frame.

The face of the double pile-driver has two sets of leading-frames; these are united at the top by a cap, and at the bottom by a sole firmly attached to the timber base by iron straps; they are still further stiffened by cross-braces, and also fastened to the cap and sole by angle-irons. These pieces are united by pine ties and braces, all roughly hewn, except the leading-frames, which are accurately planed and furnished with T-iron guides, along which the ram moves. The horsing-frame is formed of four rough pine masts, inclined toward each other, resting upon the base and united by a system of ties and braces. It supports a strong flooring, on which is placed the steam-engine. This flooring is 2 meters above the level of high tide.

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* Plate XVII.

The stiffness of this frame-work is insured by four iron stays, with tightening screws and nuts, forming the diagonals of the truncated pyramid. The horsing-frame is united to the face of the pile-driver by string-pieces, covered with a flooring, which forms the service-bridge of the apparatus.

71. MODE OF WORKING.—The flooring of the horsing-frame is about the middle of the cross-bracing. By means of a slight partition lightly nailed to the outside of these braces, a sort of open chamber is made on the horsing-frame, in the middle of which is placed an upright steam-engine of 75-horse power. Its main shaft carries a belt to the pulleys of the pile-drivers.

The engine has a feed-water heater, which is filled from below by a force-pump placed on a boat containing barrels of fresh water. Access to the platform is furnished by ladders, fixed upon the braces of the pile-driver. Each one of the pile-drivers is furnished with an endless chain, carrying, at intervals of 3.53 meters, projecting pins to raise the ram. This chain is moved by iron-toothed wheels set in motion by a wheel and a pinion, fixed upon a shaft at the upper part of the pile-driver. This shaft* has a fixed and a loose pulley, which can stop the chain at any instant. The engine-driver, who is stationed upon the upper bridge, can work this brake as easily as the overseer below. The two pile-drivers work alternately. As both receive motion from the same shaft, it is sufficient to arrange the catches so that the first ram shall fall, or remain at rest while the other rises.

The two rams† are alike; they are of oak, strapped with iron. The total height of each is 2.71 meters including the iron base and the cast-steel head, which are 13 and 31 centimeters, respectively; its total weight is 642.5 kilograms.

72. CLUTCH.—The cast-steel clutch consists of a square shoulder, by which it is united to the ram, and a head, *c*, stiffened by flanges. This head, hollowed out, incloses a claw, E, and a shoe, D, both of cast steel, and both turning around iron axles passing through the head; the claw projects beyond the head, when it falls horizontally by its own weight. Between the projections of this claw the endless chain passes; E can turn to a vertical position only when the shoe D is pushed back by the pawl P.

LUNETTE OR STRIKER-OFF.—The displacement of the shoe, serving to make fast the claw, is caused by the action of an iron piece, L, called a *lunette*‡ or *striker-off;* when this is lowered it prevents the chain from raising the ram; when it is raised, the first projecting pin of the endless chain meets the claw and raises the ram; if at any point of its upward course the ram meets the *lunette*, it is detached and falls. By this means the ram can be unclutched at any desired height. The system of pile-guides used to keep the piles along the leading-frames during the driving, permitted them to be placed very rapidly. The crab which was used to move the pile-driver served also to raise the piles; they were then attached to the guides, lowered into their proper positions, and the driving commenced. Fifteen hands were usually employed at one time.

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* Figs. 6, 7, 8, 9, 10. † Figs. 1, 3. ‡ Figs. 11, 13.

73. By experiment the time to drive two piles was found to be 35 minutes. Ten piles were usually driven during every tide; *i. e.*, four or five hours' work. From the 15th of June to the 15th of the following October there were driven 346 piles. The economy resulting from the use of this double pile-driver is as unquestionable as its evident rapidity and regularity of work. During an ordinary tide there were driven at least 10 piles to a depth of 3.57 meters at an expense of 48.65 francs, which amounts to 4.87 francs per pile. The solid contents of the embedded portion of each pile was 0.321 cubic meters. Hence the price is $\frac{48.65}{3.213} = 15.14$ francs per cubic meter driven.

The difference in favor of steam pile-driving, as compared with hand pile-driving, amounts for the 346 piles to 12,000 francs. The double pile-driver requires fewer hands than two single ones, works with greater rapidity, presents a greater stability, and drives the piles much more regularly.

74. COST.—The cost of the apparatus was 12,800 francs. It was set up by the orders of M. Plocq, Chief Engineer, from the designs, and under the direction, of M. Jacquet, Assistant Engineer *des Ponts et Chaussées.*

AWARD.—The Medal of Merit was awarded to M. Jacquet by the jury for Group XVIII.

CHAPTER VIII.

DESCRIPTION OF A NEW MORTAR-MACHINE, USED AT DUNKERQUE AND GRAVELINES.

NATURE OF THE HYDRAULIC MORTAR; PROCESS OF MANUFACTURE; DESCRIPTION OF THE MACHINE; EXPENSE OF RUNNING; QUANTITY OF MORTAR PRODUCED; MEDAL AWARDED.

(Plate XVIII.)

75. The hydraulic mortar employed in making the *béton* to be used under water is generally composed of hydraulic lime, coal-ashes, and pulverized Holland trass. These substances give a rich mortar which rapidly acquires a sufficient resistance. The *béton* formed from it is easily poured, resists the action of water, and makes an excellent foundation.

The only inconvenience in the use of this mortar is the difficulty of the manufacture, the process requiring four successive and distinct operations, for which workmen of a certain skill are necessary. These operations are the bolting of the lime-powder, the proportioning of the constituents, their mixture with water, and finally, the working up of the mortar. For humane reasons it is best to have the first and second of these operations done by machinery, on account of the corrosive action of the lime-dust upon the skin, which often causes hemorrhage of the nose, and ophthalmia. Again, the constant work, both night and day, of twenty-eight men and six horses furnished only 1.50 cubic meters of mortar per hour, *i. e.*, 36 cubic meters for twenty-four hours, which is required for 72 cubic meters of *béton* per day. It would have been necessary to quintuple the force to arrive at the required amount, viz, 350 cubic meters per day.

76. The new mortar-machine solves this problem. It furnishes by the aid of a single steam-engine the required quantity of mortar and accomplishes the four separate operations above mentioned. It is composed of four distinct parts, viz, the bolt, the distributor, the dry-mixer, the *malaxeur*, (to work up the mortar,) and the mill.

The bolt* is above the distributor; it is a revolving prism, whose surface is of sheet-iron pierced with holes twelve ten-thousandths of a meter in diameter. The sprinkled lime, slaked and reduced to powder, is brought by two men, in boxes holding a hectoliter each, and poured into a hopper, from which it passes into the bolt. The waste falls out at the other end, and can be loaded in a cart, carried away, and otherwise utilized. The sifted lime falls into a special hermetically closed chamber, furnished with windows and a movable casing, which allow inspection and access if necessary.

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* Plate XVIII, Fig. 1.

The distributor* is placed on a level with the flooring of the chamber just mentioned; it is composed of three troughs, each 1 centimeter high; but the sections are proportional to the amount of each of the constituents, viz, lime, 800; coal-ashes, 500; Holland trass, 150.

These are stored in three separate magazines, and under each one of these, the corresponding measuring-trough is placed.† The measuring-troughs have sections of 0.08 square meter, 0.055 square meter, and of 0.015 square meter, respectively. They rest by their upper edges upon the same plate.‡ A disk, 0.006 meter thick, fixed to a vertical rotating shaft, and scraping the lower edges of the troughs, has an opening larger than either of them, so that by a revolution of the shaft the bottom of each trough is successively opened and shut.§ Below each trough is another, precisely similar, resting upon a plate by its edges, and not connected with the axle of the movable disk; between the two troughs, thus placed one above the other, there is only sufficient space for the motion of the revolving disk. A second similar disk fixed to the same shaft closes the bottoms, in the same way as the upper disk closes those of the upper troughs. At the same time the openings of the two disks are placed in such a way that neither of the upper troughs can be opened at the same time with the corresponding lower ones. These disks are moved by bevel gears, *m n*, ‖ attached to the principal shaft of the machine. By a simple clutch the distributor is stopped or set in motion, at will. The materials pulverized, and placed above the upper troughs,¶ fall into them; then, as the disks revolve, the lower trough are filled and do not allow their contents to escape until the upper disk has shut off all communication between corresponding troughs; the motion continuing, the lower disk opens the lower troughs and allows the contents to fall into the mixer. The disk-shaft makes seventeen revolutions per minute; hence these troughs are filled and emptied seventeen times per minute.

77. THE MIXER.—The mixer,** having its mouth below the distributor, consists of a fixed cast-iron cylinder, furnished with a horizontal movable shaft extending its whole length, and set in motion by gearing on the outside. This shaft makes twenty revolutions per minute, and is furnished with iron paddles uniformly distributed upon its four sides, and inclined about 45° to the axis of the cylinder.

The head of one of these paddles describes a circumference, and the materials poured in at one end are mixed and carried toward the other end. About the middle of the cylinder a rectangular opening, with iron cheeks, allows the operation to be watched. Through this same opening two water-pipes pass, throwing jets of water with a head of 2 meters. In the rest of the cylinder the mortar is worked up, whence it issues perfectly homogeneous, and falls upon the rolls of the mill.

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* Plate XVIII, Figs. 3 4, 5, 7, 8.

† Plate XVIII, Fig. 4.

‡ Plate XVIII, Figs. 5, 8.

§ Plate XVIII, Figs. 4, 8.

‖ Plate XVIII, Fig. 3.

¶ Plate XVIII, Figs. 3, 4, 5, 8.

** Plate XVIII, Figs. 6, 12, 18, 19.

78. THE MILL.—The mill* consists of three rolls, of unequal diameters, moved by cog-wheels upon their axles.† In considering the appearance of the mortar as it comes out of the *malaxeur* or mixer, the mill might be supposed superfluous; notwithstanding, it was decided to retain it, since mortar made in the ordinary way has a greater density than is attainable by a simple mixing. The mill gives this last touch, and overcomes the foregoing inconvenience.

The machine is easily taken apart, so that it is only sufficient to provide beforehand a few pieces, liable to be worn out or broken, to be sure that the manufacture of the mortar will not be interrupted.

79. STEAM-ENGINE.—The motor is a steam-engine of 6 horse-power, placed in an adjoining room. It makes eighty-five revolutions per minute, and moves both the shaft for the bolt and the main shaft of the machine, properly so called. This main shaft moves the distributor by a belt, and the *malaxeur* and mill by cog-wheels.

80. Fourteen hands suffice to work the establishment.

	Francs.
The expense is per hour	4.25
Oil, charcoal, &c	2.00
Total	6.25

The *quantity of mortar* produced being constantly 8 cubic meters per hour, the price of making the mortar is 0.781 franc, without considering the rent of the steam-engine. This mortar-machine has been used with perfect success for the reconstruction of a scouring-basin at Dunkerque and a dock at Gravelines.

81. Its erection is due to M. Jacquet, Assistant Engineer, under the direction of M. Plocq, Chief Engineer of the ports of Dunkerque and Gravelines.

AWARD.—The jury for Group XVII awarded to M. Jacquet ‡ the Medal of Merit.

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* Plate XVIII, Figs. 12, 17. † Plate XVIII, Figs. 16, 17.

‡ I am indebted to M. Plocq for the valuable drawings which accompany this report.

CHAPTER X.

DESCRIPTION OF THE AUBOIS CANAL-LOCK, SITUATED ON THE SIDE CANAL OF THE LOIRE RIVER.

Method of emptying and filling the lock by the process invented by the Marquis of Caligny, viz, by means of oscillating liquid columns; Time to fill or empty the lock; Amount of water saved by this process; Cost; Medal awarded.

87. Process invented by the Marquis of Caligny.—We know that for each passage through a lock, whether up or down, a quantity of water must be drawn from the upper bay to fill up the lock a height equal to the difference of level between the two bays; this height being called the lift of the lock, and the volume of water required for this purpose, the prism of lift. The system invented by the Marquis of Caligny and applied to the Aubois lock, has for its object to diminish this waste by causing water from the lower bay to ascend into the lock-chamber when the latter is to be filled; and also by making part of the water in the lock-chamber ascend to the fore-bay when the lock-chamber is to be emptied. The system is founded on the known properties of oscillating liquids, which will presently be explained.

88. The work consists—

1st, (Figs. 17, 18,) of a full-centered aqueduct, *a b d*, 1.20 meters wide, 1.55 meters high under the keystone, and having its bed on a level with the bottom of the lower bay; the depth of the latter being 1.80 meters, the *intrados* of the keystone is 0.25 meter below the level of the lower bay. This aqueduct, which is semicircular between the two heads, empties into the lower gate-chamber, *l*, by an enlarged opening, (Fig. 22,) and on the upper side it connects with two separate reservoirs, X and Y, (Fig. 17,) situated behind the upper gate-chamber.

2d. Of a discharging-channel or saving-basin, *i s t*, connecting the reservoir Y with the lower bay by a sluice, (*c*); the other reservoir X communicates with the upper bay.

3d. Of two vertical movable pipes, *q*, *r*, open at both ends, and resting upon two circular openings made in the walls of the aqueduct. One of these pipes is placed in the reservoir communicating with the upper bay, and the other in the one communicating with the lower bay. Both pipes rise 0.10 meter above the level of the upper bay; the lower-bay pipe, *r*, is 1.48 meters in diameter and 3.57 meters high; the upper-bay pipe, *q*, is 1.40 meters in diameter and 2.97 meters high. When these pipes are lowered upon their seats, the upper extremity of the aqueduct is shut. If we raise the upper pipe, q, the water from the upper bay enters the aqueduct; if, on the contrary, we raise the lower pipe, r, the water from the lock goes into the saving-basin, or *vice versa*, according to their respective levels.

89. The manner of working is as follows: Suppose the full lock is to be emptied; we raise the pipe r, the water from the lock-chamber passes through the aqueduct under the pipe, and enters the saving-basin, which is supposed to be on a level with the lower bay. After having held the pipe r raised during a few seconds for the water to acquire its velocity, we drop it back upon its seat; the water in the aqueduct, having no issue under the pipe r, rises in the interior of both r and q, and pours over their tops into the reservoir X, and connected with the upper bay. Thus, on account of the living force of the moving liquid mass in the aqueduct, a part of the water is carried into the upper bay. When this first oscillation has ceased to cause the water to overflow from the pipes q and r, we recommence the same operation by raising again the pipe r; a new column of water issues from the lock; we interrupt again its flow under r, and a new oscillation produces a new overflow into the upper bay. As this operation is repeated the lock is emptied, one portion into the saving-basin and thence into the lower bay, another portion into the upper bay. As the difference of level which causes the oscillation diminishes, the height of the oscillation, its duration, and the amount of overflow at each new opening, diminish also; hence, after a time the oscillations become insignificant, as also the water saved by them; at this time we may complete the emptying by opening continuously the pipe r; but we may also operate otherwise and produce a new saving. For this purpose we shut the sluice-gate, c, between the saving-basin and the lower bay, and raise the pipe r; a great oscillation occurs, which causes the water to rise in the saving-basin *above* the level of the lower bay and to fall in the lock below this level; on lowering r at the end of this great oscillation we shut into the saving-basin a layer of water which will serve for filling the lock, and we have at the same time caused a difference of level between the lock and the lower bay sufficient to make the lower lock-gates open spontaneously. The layer of water obtained at Aubois by this final oscillation is 0.15 meter thick.

90. If it is required to fill the lock we commence by employing the layer of water stored in the saving-basin. For this purpose we raise the pipe r, and the water being higher in the basin than in the lock, it enters the latter, producing thereby an oscillation, which causes the level in the lock to be *above* that in the basin, and *lower* in the latter than in the lower bay, so that this first volume introduced into the lock comprises, not only that which has been raised by the previous emptying, but also another portion taken from the saving-basin, *i. e.*, from the lower bay. At the end of this initial oscillation we let fall the pipe r, open the sluice c, and proceed in another manner. We

raise the pipe *q;* the water from the upper bay enters the lock through the aqueduct; at the end of several seconds it has acquired its velocity, then we let fall the pipe *q* and at the same instant raise the pipe *r;* the water in motion in the aqueduct then produces the effect known as *aspiration* upon the water of the saving-basin, which has already been put in communication with the lower bay, and draws it by an oscillation into the lock; so that the volume introduced by this last operation consists of two portions, the first portion being taken from the upper bay to generate the velocity, and the second from the lower bay by utilizing this velocity. At the end of the oscillation we let fall the pipe *r*, raise the pipe *q*, and a new oscillation brings into the lock a new volume; we continue this operation until the diminution of the difference of level between the upper bay and the lock causes the oscillations to become insignificant; from this moment we keep the pipe *q* raised, and thus finish the filling. This prolonged opening produces a final oscillation, by which the water rises in the lock higher than in the upper bay, and opens spontaneously the upper lock-gates.

91. This canal-lock has been in operation since 1868, and we find—

1st. That seven or eight oscillations suffice to fill or empty the lock in five or six minutes.

2d. That for filling the lock without using the reserve in saving-basin, the volume of water taken from the lower bay is 0.41 V, V being the prism of lift, so that the saving by this operation is about two-fifths of V.

3d. That during the process of emptying, the volume sent into the upper bay is about 0.386 V, without considering what is saved by the final oscillation. The sum of the volumes raised by the two operations is (0.41 + 0.386) V = 0.796 V. By utilizing the great final oscillations the saving amounts to 0.90 V.

This system of lock, while it economizes the water used, produces neither lowering in short bays, nor exaggerated velocities in the narrow passages; and constitutes an ingenious use of the properties of liquids in motion. Its application to the Aubois lock cost about 40,000 francs, but much of this was owing to the difficulties of position and the nature of the soil which required special precautions. A considerable economy might be made by placing the aqueduct along the side-walls of the lock.*

92. AWARD.—The jury for Group XVIII awarded to the Marquis of Caligny the Medal for Progress.

EXPLANATION OF THE FIGURES.

Fig. 17 represents the lock at Aubois on the lateral canal of the Loire River.

i s o is the saving-basin.

a b d is the underground aqueduct.

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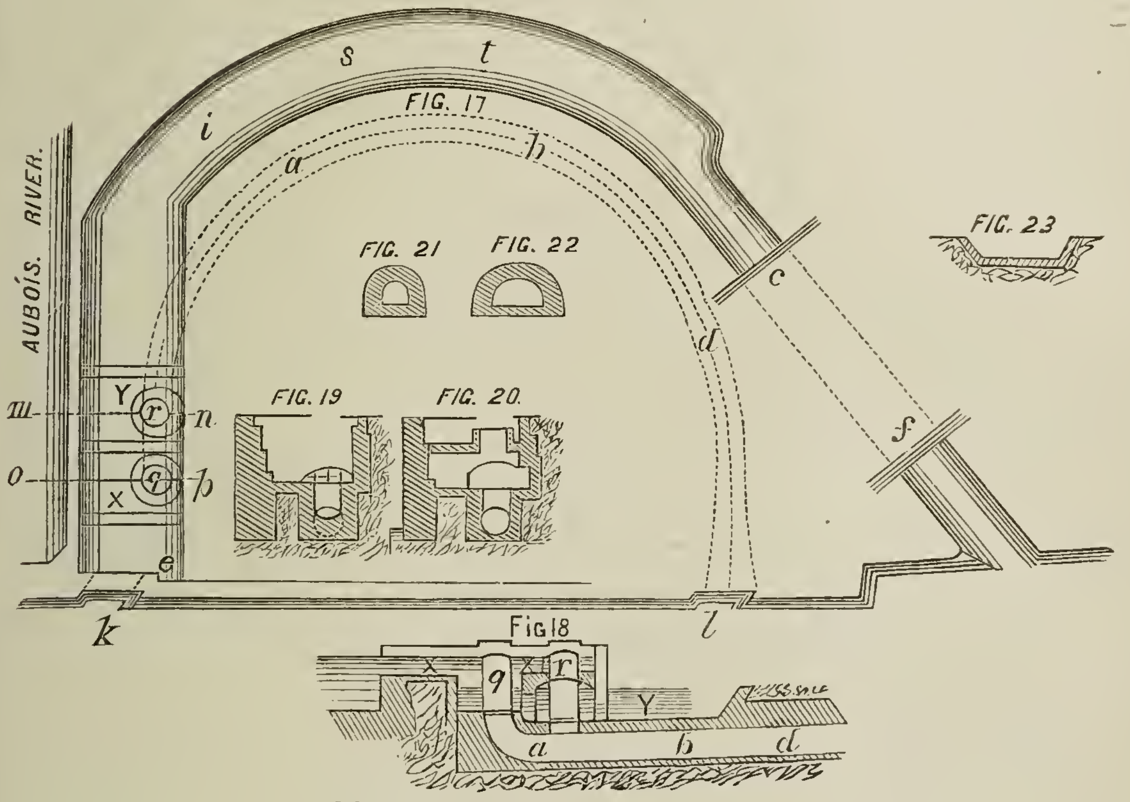
* I am indebted to Mr. Lagrené for information and drawings relating to this work.



The Aubois Canal Lock.—Art. 87.

k l is the lock; *k* the upper, and *l* the lower gate-chamber.

Fig. 18 represents the longitudinal section *e q r* of the two reservoirs X Y, and of the aqueduct *a b d*, with the lifting-pipes *q* and *r*.

Figs. 19 and 20 represent sections of the reservoirs X and Y, made by the planes *o p* and *m n*.

Fig. 21 is the section of the aqueduct.

Fig. 22 is the section of the aqueduct at *l*, the place where it discharges into the lower gate-chamber.

Fig. 23 is the cross-section of the saving-basin.

APPENDIX.

NATIONAL SCHOOL OF ROADS AND BRIDGES, AT PARIS.

History; Admission of students; Internal régime; Salary of students; Direction and administration; Instruction; Courses of lectures; Projets; Examples to illustrate the meaning of the term "projet"; Projet for a traveling-crane; For a crystal palace; Abridgment of the graphical work: Conferences; Field-work; Excursions; Examinations; Judgment of the projets; Rank of the students; Prizes.

Programmes of the courses of lectures and projets, viz: Construction and care of roads; Resistance of materials; Hydraulics; Bridges; River-improvements; Canals and water-works; Tidal, coast, and harbor works; Architecture; Agriculture and agricultural hydraulics; Mineralogy and geology; Fortifications; Steam-engines; Railways; Political economy; Administrative law; Chemistry applied to the preparation and assay of the materials of construction, and the analysis of agricultural products; Conférences upon the electric telegraph; Conférences and manipulations in photography; Conferences upon pisciculture; The instruction in drawing and sketching; Lessons in German and English; Lithographs of the lectures; Missions; Foreign students, (élèves externe;) Auditors; Library; Gallery of models; Portfolio, (collection of designs distributed to the graduates;) Chemical and photographic laboratories; Depot of the instruments of precision; Depot of machines; A detailed description of the engineering laboratory, with an account of the machines and apparatus for practical instruction and research; Budget and expenses; Acknowledgments; Diploma awarded.

93. History.—This school was founded by the celebrated engineer Perronet, in 1746, for the purpose of instructing in a more thorough manner the engineers of the kingdom, who had previously been organized under the title "*Corps des Ponts et Chaussées.*" The functions of this corps are as follows: First, to prepare the projects for the great public works undertaken by the state, such as river and harbor improvements, light-houses, roads, railroads, bridges, &c.; second, to superintend the construction of the works; third, to regulate the accounts and liquidate the expenses thus incurred.

Private companies executing similar enterprises have frequently intrusted their works, by an authorization of the government, to *ingénieurs des ponts et chaussées*, these engineers being in effect temporarily detached from the service, without losing either their rank or their right to advancement.

Admission.—For the last eighty years, twenty students, selected annually from the *élite* of the graduates of the Polytechnic School, have been admitted into the School of Roads and Bridges; these, after graduation, enter the "*Corps des Ponts et Chaussées.*"

INTERNAL RÉGIME.—The internal *régime* is that of semi-liberty, forming a transition between the previous military discipline of the Polytechnic School and the complete emancipation of the young graduate, influenced by a sense of duty and responsibility.

The students lodge and take their meals in the city, and are required to be present at the school from November to June, daily, from the hours of $8\frac{3}{4}$ a. m. to 5 p. m., except one hour for breakfast; and during this time no one is allowed to leave school without special permission from the officer of service.

SALARY.—The salary of each student is 2,000 francs per year; at the end of his studies he receives the title of "ordinary engineer of the third class," with a salary of 2,500 francs, and is stationed in the country under the direction of a chief engineer.

DIRECTION AND ADMINISTRATION.—The director of the school is a general inspector of roads and bridges of the first class; a chief engineer, or general inspector of the second class, has the direction of the studies; these two, together with the professors, form the council which regulates the instruction and work of the students.

In addition, there is a superior council, formed by the director and inspector of the school, six general inspectors, and three professors. The object of this latter council is to determine the rank of the students and to suggest improvements in the instruction.

94. INSTRUCTION.—The instruction during the three sessions consists of courses of lectures given by fifteen professors; of *projets*, which are the special work of each student; and accessory exercises.

Courses of lectures.—The first year or third class has six courses; the second and third, five each. In addition, twenty lessons in English and the same number in German are given annually.

Course.	Number of lectures.
FIRST YEAR—THIRD CLASS.	
Applied mechanics, (resistance of materials)	40
Construction of roads	35
Agricultural hydraulics	35
Mineralogy and geology	30
Political economy	30
General processes of construction	12
Total	182
SECOND YEAR—SECOND CLASS.	
Applied mechanics, (hydraulics)	30
Construction, (bridges)	34
Construction, (internal improvement)	36
Steam-engines	25
Architecture	16
Total	141
THIRD YEAR—FIRST CLASS.	
Railways	35
Construction, (coast and harbor improvements)	35
Administrative law	40
Applied chemistry	9
Fortification	16
Total	135
Total number of lectures	458

PROJETS.—The students of the first year have to furnish eight *projets;* those of the second and third years, five each. These are equivalent to one *projet* per month, and require about one-half of the time of the student; the other half is absorbed by the lectures, conferences, and other exercises, such as composition, once a month; semi-weekly lessons in sketching, and chemical, photographic, and telegraphic manipulation; exercises in the field of leveling and surveying; visits to the workshops, &c.

PROJETS.

First year, or third class.

	Projets.
Architecture	3
Mechanics	2
Roads, (construction)	3

Second year, or second class.

Architecture	1
Mechanics	2
Great bridge	1
River improvement	1

Third year, or first class.

River improvement	1
Agricultural hydraulics	1
Architecture	1
Iron bridge	1
Harbor improvement	1

EXAMPLES TO ILLUSTRATE THE MEANING OF THE TERM "PROJET."—In order to give a clear idea of the nature of these *projets* or problems in construction and design, I will annex the programmes of two, both belonging to the second year's work, the first in applied mechanics and the second in architecture.

PROJET FOR A TRAVELING-CRANE TO BE USED IN THE CONSTRUCTION OF A STONE BRIDGE.

Part first.

The load is to be moved along the bridge, across the bridge, and vertically. For this purpose there should be established a line of railway, one rail being placed on each side of the service-bridge; upon this track a car with four wheels is to run; the platform of this car should consist principally of two wrought-iron hollow beams. Upon this car should be placed a second track, at right angles with the first, and laid upon these beams. Upon this second track a second car should be placed, carrying a crab-engine furnished with a brake, a ratchet and detent.

The present *projet* is divided into two parts. The first consists of a memoir and the sketches requisite for understanding the machine as a whole and in detail. In the memoir the arrangement of the parts should be clearly described, and the dimensions given to the principal pieces verified. Finally, the force necessary to produce each of these three motions is to be calculated, considering the effect of friction; thirty-five pounds should be the limit to the effort of a man turning a crank. The traction of the car is two per cent. of the weight. The data are as follows:

Maximum weight to be lifted	15,000 pounds.
Vertical distance to be lifted	20 feet.
Width of the first track	40 feet.

GRAPHICAL WORK.

Part second.

The students will make a general plan, an elevation, and a section; also, the details of the transmission of all the motions, the brake, the engaging and disengaging gear, and in fact everything necessary for the complete comprehension and construction of the machine. These drawings should be shaded in India ink, and the nature of the materials employed should be shown by the conventional tints.

The following programme illustrates the manner in which the architectural *projets* are given.

PROJET FOR THE CONSTRUCTION OF A CRYSTAL PALACE.

It is required to furnish the plans, the estimates, and the requisite computations for the construction of a crystal palace. This edifice is designed, like the palace at Sydenham, near London, for the reception of various scientific collections, and also for the permanent exhibition of the most remarkable specimens of the industrial and the fine arts. We suppose the site to be in the new park, (Bois de Boulogne, at Paris,) on a suitable eminence, in the vicinity of an artificial lake. The palace should contain—

1. A spacious vestibule, in which may be placed the offices, a police-station, rooms for firemen, engines, &c.

2. A grand nave, or central portion, having a clear span of 130 feet and a length of 800 feet, intended to serve as a winter-garden, arranged so as to give a vivid idea of the floras of the different portions of the globe, with fountains, basins, and the reproduction of ancient edifices; also, the appliances for concerts and public speaking.

3. The galleries for the exhibition of the different products; these should be divided into three principal portions, devoted respectively to art, to science, and to industry; this last portion should contain half of the disposable space. The height and width of these galleries may vary from 30 to 50 feet. They should present an agreeable appearance should be easy of access, and provided with an abundance of light, that the various products may be seen to advantage.

4. Two or three refreshment-halls, with kitchens, saloons, and private rooms.

5. The apparatus for heating this vast extent, which should be placed below the level of the ground.

The edifice should be surrounded with terraces, ornamented with statues and fountains. These terraces should have a height of about 30 feet above the lake, with wide flights of steps leading down to the ordinary level.

The palace is to be constructed of glass and iron, except the basement, which is to be of cut stone. The dimensions are 800 by 400 feet. This space is to be covered by an iron roof, resting on cast-iron columns.

95. GRAPHICAL WORK.

The students are required to furnish plans of the edifice and its approaches, with detailed working drawings. These plans comprise a principal and a lateral elevation, to which should be added a transverse section on a larger scale. The details, carefully drawn on a large scale, should include everything necessary for the complete construction of the edifice. These drawings should be shaded in India ink, and the nature of the materials employed indicated by the conventional tints.

ABRIDGMENT OF THE GRAPHICAL WORK.—In order to use to the best advantage the time devoted to the elaboration of. the projects, the graphical work of the students is frequently materially diminished by substituting, for elaborate drawings, accurately-prepared sketches, drawn to a scale upon cross-ruled paper, with the dimensions carefully annexed. This system leaves more time for the preparation of the memoirs, and puts the students exactly in the situation of the engineer devoting his personal attention to the essentially intellectual part, viz, to the conception of the *projct.*

CONFÉRENCES.

In addition to the courses of lectures enumerated above, a certain number of *conférences* are added upon the following subjects, viz: Electric telegraphy, photography, railway management, and pisciculture.

Also, when exceptionally great engineering work or important processes can be made the themes of interesting communications, the administration has established *special conférences.* Thus, during the last few years, the students have been made acquainted with the following topics:

The Mont Cenis Tunnel;
The Suez Ship-canal;
The drainage of cities and the utilization of sewerage;
The process of rescuing workmen buried under caving earth;
Instructions in the management and extinction of fires;
The proper attention to be given to wounded workmen in the field, &c.

FIELD-WORK.

An accurate description of the instruments, however clear and detailed it might be, would not suffice for the instruction of engineers frequently called upon to direct great operations in levelling and geodesy. For this reason the course of instruction in roads includes a number of field operations, such as the use of the geodesic circle, the plane-table, the level, and the tacheometre.

The students have at the same time to make the preliminary survey for the location of a road. The operations are verified in the field, and recommenced when the errors exceed a certain limit. It is proper to add that these exercises made together in groups excite great interest among the students, and in a very short time they are able to execute them with rapidity and precision.

Excursions.—The session is usually terminated by excursions for sketching, for geological or agricultural observation; visits to important engineering works, such as the river-gates and bridges of the Seine, the sewers of Paris, the railway-stations, artesian wells, great workshops, &c.

EXAMINATIONS.

The students have to pass one partial examination every month, and at the end of the session a general examination upon all the permanent courses given at the school.

JUDGMENT OF PROJETS.

After each *projet* has been examined, the professor in charge collects the drawings and memoirs, and in a kind of public judgment before the class, commends or criticises the work according to its merit. Thus the students, instructed by their errors, are stimulated to greater exertion, without having their sensibilities wounded by the slightest personal allusion.

RANK.

The rank of the students according to their merit is determined by taking into account their assiduity, the examination-marks, their capacity in composition, in *projets*, in practical exercises, missions, &c.

For the purpose of examination a maximum of marks is established, varying for each subject according to its relative importance. The students are marked accordingly in their examinations and *projets*, and no one is allowed to graduate whose average does not exceed a previously established minimum.

PRIZES.

Prizes of 200 francs are awarded by the superior council in composition; also, for the best *projet* in each of the principal courses.

DISCIPLINE.

Experience has happily shown that there is very little need of a recourse to severe measures to insure order and discipline among students interested and eminently laborious.

Beside special reprimands given, students may be temporarily excluded, censured by the council, publicly reprimanded, or definitely excluded.

PROGRAMME OF THE COURSES.

96. In order to establish a rational order in teaching, and to avoid duplicating the lessons of the professors, the limits of each course have been accurately defined. The progress of science and the consequent increase of the material have necessitated a revision of these programmes. Their publication by the council of instruction of the school furnishes a most useful syllabus, both to professors and students.

The following is a *very brief* abstract of each of the principal courses and *projets* given during the last session, the object being to illustrate the method by which the professor applies his instruction directly to the problems of actual practice; accordingly, an abstract of the corresponding *projets* is appended to the syllabus of each course:

COURSE ON THE CONSTRUCTION AND CARE OF ROADS.

This includes surveying and levelling, with the use and adjustment of instruments; the construction of plans and maps; the calculations relative to excavations and embankments, together with the graphical method of balancing them; the principles which should determine the location of a road; the method of Flavier—his tables, their use; the estimation of the effects of slopes and curves upon the traction; the best form of cross-section; practical details of construction; blasting; foundations; the precautions to be taken with marshy land; excavations and embankments; removal of the fillings; the consolidation and drainage of the side-slopes; the construction of the road-bed; macadamized, paved, and asphalt roads; repairs of roads, accessory works, as road-bridges, sustaining-walls, sidewalks, culverts, drains, sewers, &c.; description of the sewers of Paris, London, and other large cities; the regulation and liquidation of the accounts.

Projets.

In connection with the course, *projets* are given. The first serves to familiarize the student with the calculation of earth-work, the graphical method of balancing the excavations and embankments, and the representation of the longitudinal and transverse sections of the road. In the second *projet*, a topographical map, with two points on the opposite borders, is given, and it is required to trace a road between these points; to determine the cross-sections for every ten meters, to calculate the excavations and embankments, the quantity of land required, the cost of transporting the materials, the cost of macadamizing or of paving, and indeed the cost of every kind of work to be performed.

In a supplement, the student is required to furnish plans for a bridge over one of the streams.

COURSE ON RESISTANCE OF MATERIALS.

This includes the theory of the center of gravity, the moment of inertia, and the center of percussion, of plane surfaces; the study of the changes of form of prisms due to the action of forces, tending to extend, to compress, to shear, to bend, or to twist them; solids of equal resistance; the complete theory of continuous girders with the graphical methods of representing the moments of flexure and shearing forces; the theory of curved pieces; the comparison of iron arched bridges with continuous-girder bridges, and suspension-bridges; resistances of surfaces, as boilers, &c.; the theory of right and of oblique arches; the graphical methods of M. Méry and Durand-Claye; thrust of earth, stability of revetment-walls; lattice-girders; American systems of trusses; theory of vibrations; vibrations of girders subjected to rolling roads.

Projets.

In connection with this course two *projets* are given:

1st. To calculate and graphically represent the moments of flexure and shearing strains for a continuous girder resting upon five supports and subjected to a permanent load, a proof load, and a rolling load.

2d. To make the designs for the construction and establishment of an iron roof according to the system of Polonceau; and the drawings to exhibit graphically the moments of flexure and the shearing strains of the rafters; also a memoir to contain the calculation of the dimensions of the principal pieces of the roof with the estimation of its total weight.

COURSE IN HYDRAULICS.

This includes analytical hydrostatics and hydrodynamics; the flow of liquids from orifices, in pipes and in open canals and rivers; the doctrine of the reciprocal pressure of a fluid and a solid during their relative motion; the measurement of the flow of a stream; the movement of gas; the theory and construction of water-wheels, turbines, and pumps.

Projets.

The *projets* in connection with this course are three in number:

1st. To furnish designs for a breast-wheel with a given fall and volume of water, together with a descriptive memoir containing the calculation of the efficiency.

2d. The same for a Fourneyron turbine.

3d. To make the calculations for the establishment of a system of water-works, for supplying a town, including the motors, pumps, water-pipes, &c.

COURSE ON BRIDGES.

PART FIRST.—*Construction in general.*

Comprising the study of the nature, quality, and preparation of building-stone, mortars, concrete, &c.; their resistance to crushing; wood employed in construction, its defects and preservation; joints and framing. Properties of cast, wrought, and plate iron; riveting; strength of riveted plates; painting and galvanizing; effects of expansion.

PART SECOND.—*Bridge-construction.*

Historical notice of ancient bridges; location; foundations on rock, on sand, and on marshy ground; foundations by means of compressed air, submarine boats; foundations with isolated pits filled with masonry, as those at Rochefort, Saint Nazaire, &c.

Masonry bridges: intrados curves; conditions of stability; construction of the curves of pressure; forms and dimensions of the piers; arrangement of the voussoirs; approaches; skew arches; construction of centers; wooden bridges; American truss-bridges; cast and wrought iron bridges; suspension-bridges.

Projets.

Two *projets* are given in connection with this course.

The first is for the construction of a great stone bridge in a city of 40,000 inhabitants. It is required—

1st. To furnish the plans, the longitudinal and transverse sections of the bridge, of its piers and abutments, and a chart of the curves of pressure, with their geometric values as estimated by the methods of Lamé and Clapeyron.

2d. Sketches showing the construction of the centers, the methods of foundation, the apparatus for lifting and placing the *voussoirs*, and, indeed, whatever may be necessary for the complete construction and understanding of the bridge.

3d. A descriptive memoir, containing the calculations for verifying the stability of the arches, piers, and abutments, together with the estimation of the height of the back-water when the river has attained its highest level.

The second *projet* is for the construction of a large iron bridge.

GREAT IRON BRIDGE.

The railway from Nantes to Chateaubriant crosses the Hocmard near its confluence with the river Erdre. The grade of the road requires the level of the rails to be from 8 to 12 meters above the low summer waters, and it is proposed to carry a double track over by an iron bridge.

The cross-sections of the valley and brook are given in a sketch annexed to the *projet.*

The bays may be formed by cast or wrought iron arcs, or straight girders, at the option of the author.

The students are required to present—

1st. The general elevation, on a scale of $\frac{1}{500}$.

2d. The elevation of the top of a pier, with half the intermediate bay or span.

3d. A part of the plan as seen from above.

4th. Another part of the plan as seen from below, (the last three drawings on a scale of $\frac{1}{100}$.)

5th. A cross-section on a scale of $\frac{1}{50}$. (This cross-section should be made half through the axis of the pier and half through the middle of the bay.)

6th. A cross-section of the arcs or girders on a scale of $\frac{1}{10}$.

7th. Sections of the principal pieces on the same scale.

8th. Such details as may be judged necessary to indicate accurately the mode of construction, and the method adopted for the foundations.

9th. A report upon the *projet* as a whole.

This report should justify the arrangements adopted, and give the practical formulas by which the dimensions of the principal parts were calculated.

Nos. 1, 2, 3, 4, and 5 should be finished drawings, *i. e.*, shaded and colored, with the dimensions carefully annexed.

Nos. 6, 7, and 8 may be simply sketches drawn to a scale.*

The limit of compressive stress upon cast iron should be 3.5 kilograms per square millimeter of section, its density being 7.20. The limit of tensile stress upon a square millimeter of wrought iron should be 6 kilograms, its density being 7.80.

COURSE ON INTERNAL IMPROVEMENTS.

PART FIRST.—*River improvements.*

Rivers in their natural state; methods for towage or propulsion; operations requisite to obtain sufficient data to ascertain the practicability of the improvement of a given river. Dredging; rectification; contraction of the river-bed; closing secondary branches; bank-defenses. Tidal rivers. Dams; special study of movable dams; systems of Poirée, of Desfontaines, of Chanoine, of Girard, &c.; construction and establishment of movable dams; means of ascending or descending the dams; side locks. Cost of river improvement by narrowing the channel; examples: the Garonne, the Meuse, the Moselle, &c. Cost of improvement by the establishment of locks and movable dams, as the Seine, the Saône, the Yonne, the Oise, &c. Difference in the price of freight before and after these improvements.

PART SECOND.—*Canals.*

Side-canals; canals with a summit level; construction of reservoirs;

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* Described in ¶ 95.

of masonry dikes. Practical details; earth-work; stanching; tunnels; foundation and construction of locks and accessory works. Diminution of the cost of freight after successive improvements.

PART THIRD.—*Water-works for towns and cities.*

Sources of water; artesian wells; rivers. Machines for raising water; hydraulic motors; pumps; steam-pumping engines. Plate-iron, and stone reservoirs. Graphical methods to determine the thickness of the arches, walls, and buttresses. Arrangements for filtering; allowance for consumption. Location and arrangement of the conduits. Calculation of the proper diameter; means of preserving the pipes from rust. Effects of sudden shocks; joints; trial before covering. Different forms and arrangements for the valves, stop-cocks, hydrants, &c. Example of the distribution in a city.

Projets.

In connection with this course two *projets* are given.

The first consists of the preliminary studies for a canal, viz: It is required to establish a canal, to accommodate boats, 40 meters long and 6 meters broad, drawing 1.80 meters. The five following cases are to be studied:

1st. For a portion of the canal so situated that one side of a ridge of compact marl forms one slope of the canal.

2d. For a portion situated in a valley having a permanent bed of gravel, filled with water during the winter.

3d. The aqueduct for traversing a brook. The aqueduct should have a section of 6 square meters.

4th. The canal enters a river, and it is required to show how the entering-lock should be constructed.

5th. Constructions in the river below the entering-lock.

Five cross-sections are to be drawn, corresponding to the five cases given above, and in addition the longitudinal sections of the lock and aqueduct. Special attention should be given to the earth-work and the foundations, and all arrangements adopted should, as far as possible, be represented upon the drawing. These drawings are to be pen-sketches, roughly shaded, and with the dimensions carefully annexed; the masonry being tinted blue if laid dry, and pink if laid in mortar. In addition, specifications of the amount and cost of the earth-works and masonry.

Second *projet.* The improvement of a portion of a navigable river.

It is required to improve a river so as to obtain a depth of 1.60 meters either by opening a *derivation*, or by building one or more movable dams with side-locks; both of these solutions to be studied and compared. The plan, the longitudinal section, and 29 cross-sections of the river are given; the banks are supposed horizontal, 2 meters above the summer waters and 1 meter above the highest waters. The soil is composed of sand and gravel resting on rock 3.50 meters below the low-water level. It is required—

1st. To return the lithographic plan with the two solutions represented upon it, the first in blue, and the second in red.

2d. A longitudinal profile of the navigable route, on the same scale as the first.

3d. The drawings to indicate the methods of constructing the principal works.

4th. An explanatory memoir.

5th. The drawings of the second *projet* to be made like those of the first.

COURSE ON TIDAL, COAST, AND HARBOR WORK.

Classification of ports and harbors; study of the action and effects of tides, currents, winds, and waves; effect of the action of the sea upon the coast; action of sea-water upon the materials of construction.

Ports and harbors of refuge; classification of ships; manoeuvers on arriving or departing from a port.

Construction of works for the protection of vessels against the waves; as moles, breakwaters, wave-screens, jetties, clear-ways, &c. Works for loading and unloading ships, wharves, quays, docks, draw-bridges, &c. Means of deepening ports and harbors; dredging; detailed study of artificial scouring-basins with sea-locks.

Works for the construction and repair of ships; floating caissons; graving-docks.

Defense of coasts against the sea. Light-houses and beacons.

Projet.

It is required to construct a sea-lock at the outlet of a scouring-basin, having an area of 50 hectares. The depth of water in the basin, together with the levels at the highest and lowest tides, are given; the soil is compact sand.

The students are required to furnish a general plan of the lock and the wing-walls joining those of the scouring-basin; longitudinal and transverse sections of the work, with the corresponding dimensions, carefully annexed. Also plans, elevations, and sections of the lock-gates, and service-bridges, with sketches of the details. Further, an explanatory memoir giving the dimensions of the principal portions, the details of construction, with the method adopted for the foundations, &c.

COURSE ON ARCHITECTURE.

Egyptian, Grecian, Etruscan, and Ancient Roman architecture.

Christian, later Roman, Byzantine, and Lombardic architecture.

French architecture before the sixteenth century, renaissance.

Composition; railway and postal edifices; light-houses, docks, arsenals, hospitals, baracks, courts, warehouses.

Heating, lighting, ventilation, and sanitary arrangements, for edifices.

Projets.

The *projets* are exceedingly varied and extend through the three years; the—

1st is for a custom-house on a railway line.

2d. For a harbor light-house.

3d. Custom-house in a large city.

4th. A naval court-house.

5th. A first-class railway station in a large city.

COURSE ON AGRICULTURE, AND AGRICULTURAL HYDRAULICS.

I.—AGRICULTURE.

Statistics of the agricultural territory and population of France. Elementary notions of vegetable physiology. Agricultural meteorology; the formation and constitution of arable land; improvement; fertilizers; agricultural machinery; preparation of the soil for the crop; preparation of the crop for the market; means of transportation.

Farming; cultivation and care of trees; their influence upon running streams.

II.—AGRICULTURAL HYDRAULICS.

Purification of water-courses. Laws affecting rivers and streams. Means of obtaining water; regulating works; constructions for the protection of river banks; legal level.

Establishment of mills.

The drainage and reclaiming of marsh-lands.

Irrigations.

Projet.

It is required to improve and render available two pieces of land, each of considerable extent: the first is a marsh which requires to be drained, and the second is on high ground, with light, dry, soil, which required to be irrigated.

The maps with contour lines for each of the pieces are given, and it is required to furnish—

1st. A general plan to show the position and arrangement of the canals, ditches, roads, plantations of trees, buildings, and the general arrangements for the two systems of drainage and irrigation.

2d. Longitudinal and transverse sections of the canals, ditches, buildings, and motor, with its accessories; plans of the portions drained and irrigated. To which should be added a memoir explaining the general arrangement, and containing the calculations made to ascertain the dimensions of the principal portions of the works.

COURSE ON MINERALOGY AND GEOLOGY.

Comprising crystallography, the physical and chemical properties of minerals, description of the mineral constituents of rocks, detailed description of each of the geological epochs, the formation of mountain-chains, volcanoes, glaciers, &c.

COURSE ON FORTIFICATION.*

With a *projet* for establishing a line of temporary fortification for the protection of a bridge.

COURSE ON STEAM-ENGINES.

Properties of gas and vapors. Mechanical theory of heat.

Stationary engines.—History; boilers; fire-grates; chimneys; apparatus to introduce and distribute the steam, as valves, cut-offs, governors, condensers, &c. Classification according to the transmission of the motion; velocity; power; dimensions of the parts; cost.

Pumping-engines: combined vapor-engines; caloric-engines.

Marine-engines and boilers: classification; dimensions of ships; towage.

Locomotives: history; passenger, mixed, freight, station, and mountain locomotives of various types; metals employed in their construction; detailed description of the parts, stability, method of balancing.

Inspection of engines and boilers; safety apparatus.

Consumption of engines: combustion and fuel; smoke-consumers.

Description of a machine-shop: machine-tools.

Organization of the locomotive service for a railway; work; load and cost of running railways; explosions; accidents.

Portable engines: use of steam-engines for the construction of public-works.

1.—COURSE ON RAILWAYS.

Introduction: relations of the load to the motive-power.

History: resistance to trains; locations; grades; curves; cross-sections; distribution of the earth-work; tunneling; bridges and viaducts. The road-bed; ballasting; cross-ties; rails; chairs; crossings; switches; signals, &c.

Stations and dependencies: rolling-stock; railway contracts; cost of establishment; traffic and receipts; comparison between railways and water-ways.

2.—CONFERENCE ON RAILWAY MANAGEMENT.

The importance of the work accomplished by railways; increase of this work; monopoly; formation of a railway system; fixed and rolling-stock; organization of the company; officers and their duties.

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* Recently introduced.

Measures for security; accidents.

Fast and slow passenger and freight trains.

Rates for passengers and goods of various kinds.

Cost of working; receipts.

Cost of working branch roads.

General results achieved by railways; advantages to the state; uniformity of price in articles of food; suppression of famine; development of agriculture, manufactures, and commerce, and consequent increase of wealth.

COURSE ON POLITICAL ECONOMY.

Analysis of production and the explanation of the industrial organization of society:

Study of the three instruments of production.

Conditions necessary to production.

Natural obstacles to a free competition; regulation and intervention of authority; reasonable public service; conditions favorable to production.

Questions relative to the different industries; market and exchange; value; price and money; representative signs; metallic signs, paper signs, paper money.

Money-lending; credit and the banks; the circulation of signs; panics.

Systems relative to international exchanges; distribution of riches; the utilization or employment of riches; conditions for the happiness and well-being of the population; general notions of statistics. Questions relating to transportation, to ways of communication by land or water, and to public works in general.

COURSE ON ADMINISTRATIVE LAW.

Including general notions upon the organization of the public powers; administration of general and local interests; public establishments.

Judicial authority: Administrative jurisdiction; method of rendering the administrative independent of the judicial authority; administrative authority in regard to public works; brief study of the rules of civil law respecting persons, property, and obligations. The construction of public works considered in relation to public finances; the relations of the state with contractors, grantees, and landed proprietors. Questions of administration relating to roads, railways, sea-coasts, harbors, navigable and non-navigable water-courses, reservoirs, water privileges for mills and factories, irrigation, and the diking of water-courses for the protection of private property; the drainage of marshes and the reclaiming of waste-lands. Legislation in respect to dangerous and unwholesome manufactories, to boilers and steam-engines.

COURSE IN CHEMISTRY, APPLIED TO THE PREPARATION AND ASSAY OF THE MATERIALS USED IN CONSTRUCTION, AND THE ANALYSIS OF AGRICULTURAL PRODUCTS.

This course includes a review of the properties of those chemical elements which go to form the materials of construction and the most common agricultural products; the most useful of the reagents; qualitative and quantitative analyses; abridged methods of assays; analyses of waters and of soils.

Properties and preparation of limes, mortars, concretes, cements, mastics, asphalts, bricks, pottery, &c.

CONFÉRENCES UPON THE ELECTRIC TELEGRAPH.

Including a description of the batteries, lines, and apparatus in use, with its application to railways, to which are added various industrial applications of electricity, viz, electro-metallurgy, the electric light, Lenoir's gas-engine, blasting rocks, and distributing time through a city by the electric clock.

CONFÉRENCES AND MANIPULATIONS IN PHOTOGRAPHY.

Three conférences are given upon photography, during which the processes are carefully explained and practically exhibited.

Independently of these the students devote four days to photographic manipulations.

CONFÉRENCES UPON PISCICULTURE.

This includes descriptions of fresh-water fish; the natural and artificial methods of culture; the influence of river improvement upon their production; legislation relative to river fisheries; sea-coast fisheries; culture of shell-fish, &c.

THE INSTRUCTION IN DRAWING AND SKETCHING.

This instruction is divided into five portions:

1st. Sketches taken from large drawings of the parts of machines.

2d. Sketches from models, with the dimensions, subsequently ascertained by measurement, annexed.

3d. Sketches of machines, motors, buildings, &c., made in public or private establishments. These sketches are drawn in pencil, without rule or compass, approximately to a certain scale. When they are finished the objects are measured and the dimensions carefully annexed to the corresponding sketch. In the interval, between two excursions, the students trace the pencil-lines with a pen.

4th. Sketches in the field of engineering works.

5th. Making finished drawings, at least one every session, from the sketches and measurements in hand.

LESSONS IN GERMAN.

These comprise explanations in French of German authors, exercises in conversation by means of explained texts, with the study of the included words and phrases, German versions and exercises. Explanation of scientific German works; study of engineering terms. Conférences upon the German language.

LESSONS IN ENGLISH.

Study of the pronunciation; elements of English grammar; translation; composition of words and the comparison of the roots with those drawn from the Greek, Latin, and the German languages; English versions; study of idioms; conversation; special study of scientific and engineering terms.

LITHOGRAPHS OF THE COURSES OF LECTURES.

97. Some of the courses of lectures given at the school are published; when, however, there is no printed work corresponding to the course, the school distributes to each student lithographic sheets, giving a *résumé* of each lecture; the sheets thus acquired form a valuable compendium, independent of the notes which each student is expected to take as the lecture proceeds.

MISSIONS.

From the 1st of June to the 1st of November, the students are sent into the departments of France, and there attached to public works in the course of construction, to be initiated into the practical portion of their profession, under the direction of the chiefs of the service.

The object of the mission is primarily practical instruction and a noviciate of the duties of an engineer. For this reason, among the instructions given to the students before their departure, it is particularly recommended that they should familiarize themselves with the accounts and administrative questions, as well as study the different problems of construction before them.

During the mission the students are required to keep a journal of the instructions they receive, the observations they make, and the works in which they participate. Account is taken, in making up their rank, of the merit of this journal, the zeal they have displayed, and the services they have been able to render.

At the end of the third year, two or three foreign missions are reserved to specially distinguished students.

England, Germany, Belgium, Holland, and Upper Italy are annually explored by these young engineers.

Other and more remote missions, to America and the Isthmus of Suez, have been assigned within a few years, and it has been deemed expedient to give them to professors of the school. The collections sent to the Vienna Exhibition contain three important specimens of the results of these missions; they are the three following works:

Studies of the architecture of Lombardy, By Prof. M. F. de Dartin.

Public works of the United States of America, by Prof. M. Malezieux.

The ancient art of building as exhibited by the Romans, by M. Choisy, Engineer of Roads and Bridges.

FOREIGN STUDENTS, (ÉLÈVES EXTERNES.)

Besides the engineering students destined to the state service, the administration of the school is authorized to receive some eight or ten students annually, French or foreigners, who after a severe examination are found qualified to enter. The subjects of this examination are as follows: Arithmetic, algebra, geometry, analytical and descriptive geometry, shades, shadows, and perspective, stereotomy, differential and integral calculus, analytical mechanics, architecture, physics, composition, and drawing.

These students are admitted to the same courses, execute the same graphical works, and submit to the same examinations. Their instruction during the three years is entirely gratuitous. They may obtain permission during the intervals of the sessions to visit the public works of the state in process of construction.

THE AUDITORS form a third category of persons, admitted only to the lectures, permission having personally been obtained from the director of the school.

LIBRARY.

The school possesses one of the richest engineering libraries in the world. Founded by Perronnet, who bequeathed to it his books and manuscripts, enriched by numerous purchases and legacies, it contains not less than 40,000 volumes. Before 1871, the only catalogue was in manuscript transcribed by the librarian, M. Schwebelé. Recently, however, a printed catalogue has been prepared and distributed to all the engineers in the service, and arrangements have been made to allow them not only to consult the library but to borrow books under certain restriction.

GALLERY OF MODELS.

The eminent founders of the schools of Roads and Bridges understood from the beginning the importance of placing before the students as examples, specimens of machines, and different types of the most important works.

These representations, which go back to the origin of the school, have been continued year by year, and were materially augmented by the successive exhibitions of 1855 and 1867.

The galleries of the school contain at present more than twelve hundred models or drawings, divided into twelve groups or series, corresponding to each course of construction.

Many of those models, on account of their exquisite workmanship and finish, are exceedingly valuable and interesting. A general catalogue contains a special notice of each model, gives a summary description of it, and, when it represents a piece of engineering, gives also its principal dimensions, the date and cost of its construction, with the names of the engineers who took part in the work. The preparation of this catalogue is the work of Professor Baron, who has charge of the galleries.

PORTFOLIO OF THE SCHOOL OF ROADS AND BRIDGES.

Collections of drawings distributed to the graduates.—In 1821 and 1825, a number of designs of important works were lithographed and distributed to the students. This distribution was re-organized in 1853, under the title of "Portfolio of the school." It is a collection of drawings, accompanied by a descriptive text of the most important engineering-works in France and elsewhere, engraved every year and gratuitously distributed to the students. These drawings are arranged in the following groups or series:

FIRST SERIES.—EXECUTION OF WORK; GENERALITIES.

Section A.—Instruments of precision generally, employed by engineers.
Section B.—Workman's tools.
Section C.—Earth-work.
Section D.—Pile-driving and dredging.
Section E.—Lime-kilns and mortar-machines.
Section F.—Pumping-machines; sounding-apparatus, diving-bells, &c.

SECOND SERIES.—ROADS.

Section A.—Plans and sections.
Section B.—Special constructive works.
Section C.—Machines for rolling and cleaning roads.

THIRD SERIES.—BRIDGES.

Section A.—Stone bridges.
Section B.—Wooden bridges.
Section C.—Iron bridges.
Section D.—Centers, scaffoldings, foundations.
Section E.—Draw-bridges.

FOURTH SERIES.—RAILWAYS.

Section A.—Plans and sections.
Section B.—Establishment of the track.
Section C.—Constructive works.
Section D.—Fixed and rolling stock.
Section E.—Stations.

FIFTH SERIES.—INTERNAL NAVIGATION.

Section A.—Plans and profiles.
Section B.—Constructive works in rivers.
Section C.—Constructive works in canals and side canals.
Section D.—Canals with a summit-level.

SIXTH SERIES.

Section A.—Plans and profiles.
Section B.—Moles, breakwaters, quays, &c.
Section C.—Scouring-basins.
Section D.—Floating-basins, locks, docks, &c.
Section E.—Works for repairing ships.
Section F.—Light-houses.

SEVENTH SERIES.—ARCHITECTURE.

Section A.—Generalities, drawings.
Section B.—Railway buildings.
Section C.—Marine buildings.
Section D.—Miscellaneous edifices.

EIGHTH SERIES.—HEALTH OF CITIES.

Section A.—Water-works.
Section B.—Drains.

NINTH SERIES.—RURAL ENGINEERING

Section A.—Process of draining and reclaiming lands.
Section B.—Irrigations.
Section C.—Plantations, protection of river banks.
Section D.—Factories and rural establishments.
Section E.—Pisciculture.

TENTH SERIES.—STEAM-ENGINES.

Section A.—Boilers.
Section B.—Locomotives.
Section C.—Marine-engines.
Section D.—Stationary and portable engines.

ELEVENTH SERIES.—MACHINES AND APPARATUS.

Section A.—Motors other than steam.
Section B.—Machine-tools.
Section C.—Apparatus for loading and unloading; cranes, &c.
Section D.—Apparatus for heating and ventilation.
Section E.—Machines not classified.

These drawings, made on a very large scale, contain specimens of new machines as well as the most remarkable works of engineering, accompanied with full and complete details. They contain also documents, taken by the permission of the authors, from such rare or costly works as would otherwise be inaccessible to the majority of the engineers.

LABORATORY.

The primary object of the laboratory of the school is to familiarize the students with the chemical manipulations and analysis. For this purpose they are called upon twice a year to perform during one week assays and analyses having special reference to their profession. Another object of the laboratory is to make gratuitous analyses and assays of calcareous rocks, limes, cements, puzzolanas, mortars, and other materials of construction; also practical studies of manures, fertilizers, drinking-waters, and sewerage, which interest so much both agricultural and hydraulic engineers. Private parties as well as engineers sending to the director of the school specimens which interest them, receive the results of the analyses gratuitously. For the last six years the annual number of specimens thus analyzed has exceeded one thousand.

PHOTOGRAPHIC LABORATORY.

Since photography has become such a valuable auxiliary to the engineer, a laboratory has been established to enable the students to perform their photographic manipulations. The experience of several years shows that a few exercises with intelligent direction and mutual instruction suffice to give them a proper degree of skill. But the laboratory also serves to multiply or reduce plans and drawings, thus economizing the labors of the draughtsmen employed in making the plates for the various publications issued by the school.

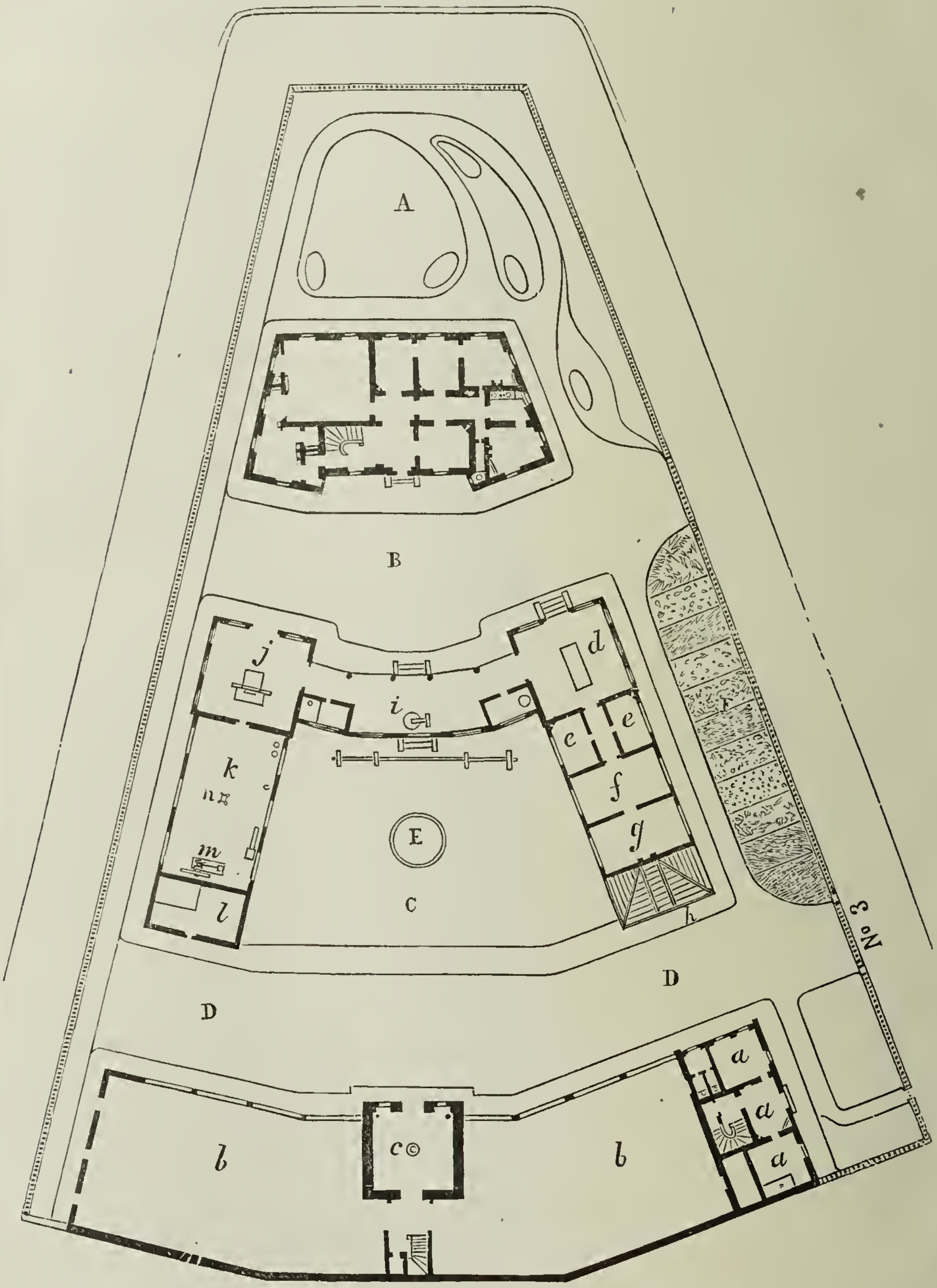
DEPOT OF THE INSTRUMENTS OF PRECISION.

The object of this depot is to keep in repair all the instruments used by the students in the field. It also serves to centralize the reception, distribution, and repair of all instruments accorded by the government to its engineers. They are ordered from the best makers and subjected to the control of a minute verification. Also the depot receives those instruments not required, puts them in order, and sends them where they are needed. This service is under the direction of Professor Baron, aided by Conductor Klein.

DEPOT OF MACHINES.

The depot of machines accomplishes a similar object and answers a corresponding need, viz, to order, try, and send machines and apparatus required by the engineers of the state. It also receives and stores valuable machines, such as portable engines, pile-saws, pumps, &c., that are left in the field after the completion of engineering works. These machines are

FIG. 1.—PLAN OF THE LABORATORY.



a a a porter's lodge; *b b* sheds for machines, etc.; *c* anemometer tower; *d e f g* chemical laboratory; *h* green-house; *i* steam-engine; *j* atelier or workshop; *k* experiment hall; *l* store and boiler rooms; *m* Hugon's gas-motors; *n* hydraulic press. A ornamental garden plot. In the rear is a building containing galleries, council-rooms, etc. B and D open spaces; C open court; E water reservoir; F gardens.

put in order and remain ready for use, to be sent upon the proper requisition.

Inventories both of the machines and instruments are kept at the school, so that at any moment an account can be rendered of the value, place of use or deposit, of every machine or instrument belonging to the service throughout France.

Professor Mangon, aided by Professor Durand-Claye and M. Klein, have charge of this service.

ENGINEERING LABORATORY.

98. The object of this establishment is as follows:

1st. To facilitate the practical instruction of the students and the progress of constructive science, by furnishing the professors and other engineers the means of observation and experiment otherwise unattainable.

2d. To bring together those models and collections which, on account of their weight or mode of action, could not be properly placed in the galleries of the school.

3d. To serve as the central depot of the machines above described.

4th. To provide examination-halls and accommodations for councils or commissions.

The work of construction commenced in 1867 and terminated in 1869.

Fig. 1 is the plan of the whole.

A represents an ornamental garden-plot. The building directly behind A contains on its lower story the lodging of the conductor of roads and bridges, attached to the depot, and also the examination and council halls. In the second story is a great hall for models. In the sheds *b b*, placed at the other end of the establishment, are stored machines and apparatus of the depot proper and such other models as are too heavy or too bulky to be placed in the gallery on the second story. The laboratories and workshops occupy most of the space between B and D. The rooms *d*, *e*, *f*, *g* are devoted to chemistry. On the other side are established the workshop *j*, and the experiment-room *k*, principally devoted to the assays of the resistance of the materials of construction and to other engineering researches. These two one-story buildings are united by a covered gallery.

The picturesque view taken from a point beyond the plot A, shows the arrangement of this side of the establishment. The tower, the upper part of which is seen behind, is situated at c in Fig. 1. It is surmounted by an anemometer, and contains besides the attached apparatus, a large reservoir of water. The free space C and the court DD between the laboratories, afford room for the trial of the machines bought for the depot before they are sent into the departments; also for hydraulic experiments, which will presently be described.

The plot of ground F is devoted to the culture of plants to illustrate the course of agriculture.

The workshop, *j*, contains a forge and its accessories, lathes, drilling and planing machines; these machines are put in motion by a steam-engine.

Behind the forge a little foundery is established with two blast-furnaces, in which several kilograms of iron or bronze may be melted.

This apparatus, besides its habitual use, allows the students to see, upon a small scale, it is true, but in detail and at leisure, the action of tools upon different varieties of metals, such as cast and wrought iron, Bessemer, Krupp, and ordinary steel, &c., the elementary operations of forging metallic pieces, the tempering of tools, &c. It allows them time to carefully examine the appearance of melted metals, to judge of their temperature by their hues, and in a word to acquire a multitude of elementary practical notions, which they should possess when they enter upon their summer work and which cannot be given during their visits to great machine-shops, where their attention is distracted from such details by the great operations going on around them.

The experiment hall *k* (Fig. 5) placed behind the workshop, contains one of Hugon's gas-motors, *m*, of a single horse-power. This little machine, which is put in motion by lighting a gas-burner, is invaluable in a scientific establishment, where the work varies every moment and is frequently interrupted. By means of belts and shafting the power is carried into the workshop, where it moves the machine-tools and a grindstone. In the hall *k* it works a mill for grinding cements, puzzolanas, &c.; a circular saw for cutting wood and stone to be tested; an optician's lathe, for grinding and dressing glass and hard stones, and an air-pump, by which compressed air may be sent into the laboratory, or a vacuum produced in previously prepared jars.

By means of tension-drums in the same hall all other machines, whether for instruction or experiment, can be put in motion. Thus hay-cutters and various other agricultural machines are worked and described before the students. Recently a magnetic machine, moved in the same manner, has served to extract from certain arable earth its particles of titanate of iron, the study of which is of so much scientific interest.

The hydraulic press for measuring the resistance to crushing of stones, bricks, and other materials of the same nature, is at *n*, in the middle of the hall. The forcing-pump and manometer are placed near the wall, and communicate with the press by pipes passing under the asphalt pavement.

A machine to measure the tensile strength of cements, platform-scales, and a few other pieces of apparatus, form at present, the contents of the room. Arrangements, however, have been made for putting in a large testing-machine to measure the strength of iron and steel, subjected to various stresses, and to determine their coefficients of elasticity.

The building *l* behind the hall *k* serves as a store-house, and contains also a steam-boiler for heating a portion of the establishment. There

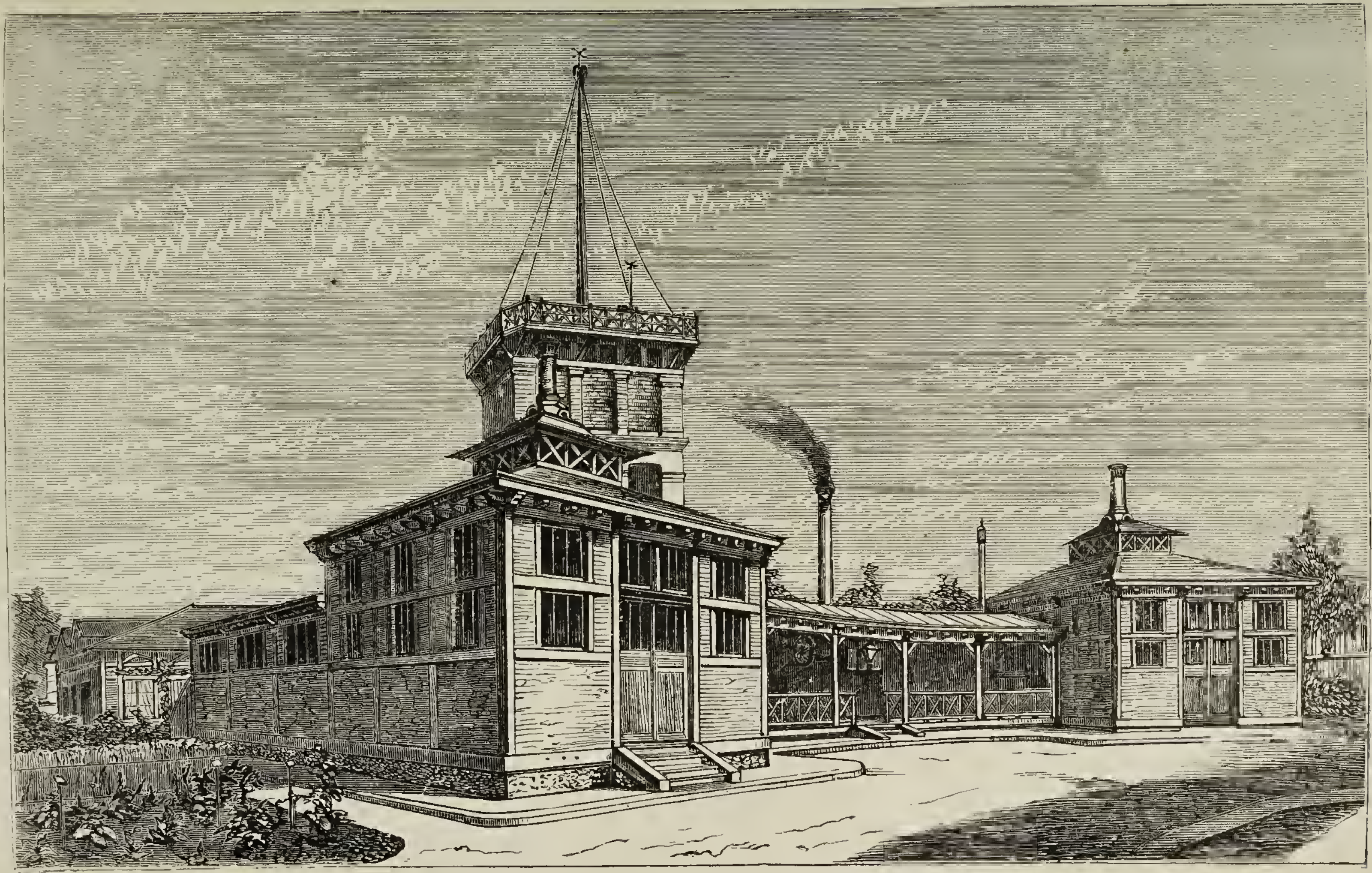


FIG. 2.—View of the laboratory and the anemometer-tower.

is also a steam-engine of 8-horse-power set up in the gallery *i*, which can work, by means of belting, any machine placed in the court B, but ordinarily it drives shafting, to which can be connected machines of different kinds—pumps, pile-drivers, &c., placed in the court C.

The basin E, 5.5 meters deep, allows the pumps and other hydraulic machines to be tested, before sending them to be used by engineers in the field.

Besides moving these temporary machines, which vary with each day's requirements, the steam-engine *i* works a rotative pump at the right of the basin E, thus supplying iron canals placed in the court, which, after a longer or shorter course, empty into the same basin, E. These canals, which, on account of the power of the engine, can supply 300 liters per second, are fitted with weirs, floats of different kinds, and the apparatus requisite to repeat before the students all the experiments on the flow and gauging of liquids, which are so difficult to render intelligible by lectures, however perfect the descriptions may be. We may, by introducing a quantity of sand, imitate in these artificial currents certain phenomena of erosion of back-water, &c., useful to see on a small scale before meeting them in the great natural water-courses, where their general action is so difficult to determine on account of the great space over which it extends.

The disposable volume of water is sufficiently great to allow physicists to undertake new experimental researches, and to give the service of the "Depot of the Instruments of Precision" the means to prove and determine the constants of the gauging apparatus, such as Woltmann's sail-wheel, Darcy's tubes, &c., which they have too often been obliged to receive on trust from the makers.

When the rotary-pump above mentioned is not in use, the steam-engine can work a forcing-pump, which serves to force water from the basin E through a pipe 0.18 meter in diameter up into a wrought-iron tank capable of holding 20 cubic meters, placed in the tower *c*, (Fig. 1,) at a height of 12 meters above the ground.

A descending pipe of 0.18 meter in diameter leads from the bottom of the tank to an open vessel a few meters in front of the basin E. Under this vessel is placed a drum, capable of receiving mouth-pieces, nozzles, orifices, &c., desirable to be experimented with, under varying heads up to 14 meters. The water thus raised, after having served for these experiments, falls back into the basin E, whence it is sent back to the tank by the forcing-pump; so that the same volume of water can circulate through the apparatus under test, as long as may be desired.

This part of the establishment furnishes the means of repeating all the experiments relating to the motion of water under pressure, and of undertaking, upon a really practicable scale, the researches necessary for the solution of the numerous problems which are raised in this branch of applied hydraulics, so important in the establishment of water-works for towns and cities.

The building *d*, *e*, *f*, *g*, on the other side, is devoted to chemical researches; the room *d* contains an oven for the assay of lime or bricks, a muffle-furnace heated with coal oil, a sand-bath, a boiler for the fusion of asphalt and other similar products, an alembic, an enameling-lamp, and other useful implements.

The hood which surrounds the chimney, communicates with the outside air and gives, as well as the lantern-roof, a perfect ventilation.

e e are two little balance rooms.

The room *f* is devoted to delicate researches requiring the use of metallic instruments and the absence of all acid and alkaline vapors. Here is an automatic intermittent aspirator, used in the researches on the slow combustion of organic matter, a gas-meter for 50 burners, serving as an aspirator or ventilator, moved by a weight which descends into a small hole made by sounding in the court C; also a spectroscope, a saccharimeter, &c.

The room *g* is exclusively reserved for gas analysis, and contains a marble mercury-table, a vessel of mercury, two Regnault's eudiometers, a Ruhmkorff coil, a cathetometer, and graduated tubes for special processes of analyses by the students. This room is set against the greenhouse *h*, into which are conveyed, by means of tubes, the gases requisite for certain experiments in vegetable physiology performed there.

Two vessels, lined with zinc or lead, are arranged in the gallery *i*, to receive the specimens of mortar to be exposed to the action of fresh or salt water, or different solutions.

Two little chambers are arranged in the corners of the gallery *i*; the one at the left contains a great drying-room, heated by a current of hot air from above downward; the one at the right contains a gasometer of 500 liters, and gives access to one of the stairways leading to the old quarry under the whole establishment. This quarry forms a cellar with a nearly constant temperature.

The last building which remains to be described is the square tower shown in Fig. 2, and designated by the letter *c* in Fig. 1.

The ground-floor of this tower is occupied by some specimens of the materials of construction. The first story contains the electric registering apparatus of the anemometers, tracing the velocity of the wind in a continuous manner, and indicating its direction every ten minutes; also, Hipp's barometrograph, and the reservoir of a rain-gauge for the verification of barometers delivered by the service of the "Depot of instruments of precision," with specimens of the principal electrical instruments used in the hydraulic and railway services.

The next story contains a wrought-iron tank, having a capacity of 20 cubic meters, supplied by the water-works of the city.

Besides its use for the hydraulic experiments above mentioned, this reservoir feeds a Bunsen filter-pump, supplies all the rooms, and prevents any serious disaster in case of fire. Gas, as well as water, is distributed throughout the establishment.

It would be too long, and perhaps premature, to indicate here the numerous researches which engineers may make, supplied as they are

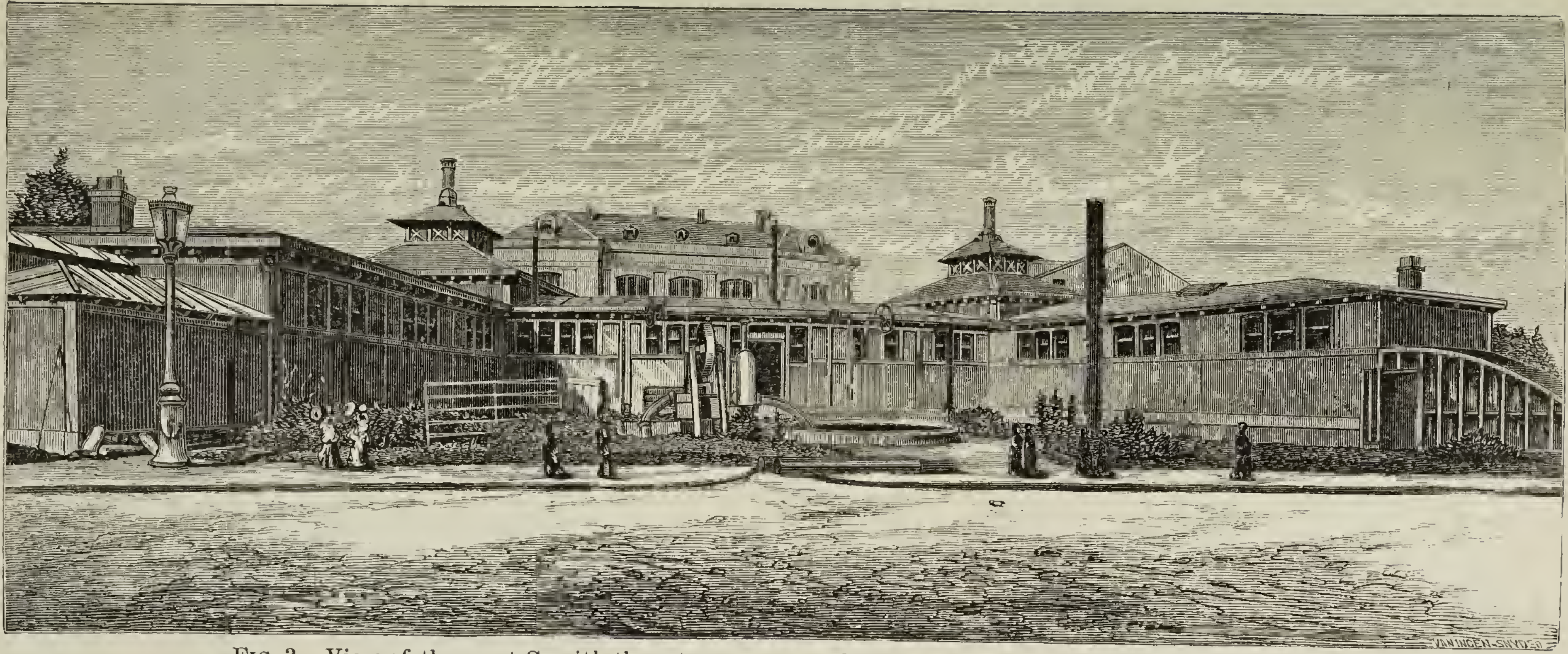


FIG. 3.—View of the court C, with the rotary-pump worked by a steam-engine in the gallery behind.

with the above-mentioned buildings thus completely equipped. We may, however, add that there is now going on a series of experiments upon the hardening of mortars and cements, and upon the preservation of the materials of construction by coatings of different natures. The duration of these assays, a duration which it would be impossible to obtain in any other than a public establishment for scientific and practical researches, will give them an unquestioned utility.

DESCRIPTION OF THE PLATES.

FIG. I.—Plan of the laboratories.
  A, ornamental garden-plot. The building directly in the rear of A contains the gallery of models, and the council and committee rooms.
    a, *a*, *a*, porter's lodge.
    b, *b*, shed for machines and apparatus.
    c, anemometer tower, containing also a large water-tank.
    d, *e*, *f*, *g*, chemical laboratory.
    h, green-house.
    i, a steam-engine.
    j, atelier, or workshop for the preparation of the data for experiments.
    k, experiment hall.
    l, store and boiler-room.
    m, Hugon's gas-motor.
    n, hydraulic press.
  B and D, open spaces.
  C, open court.
  E, water reservoir.
  F, garden for plants to be used in the lectures.
FIG. 2.—View of the laboratory *p i f*, taken from a point situated beyond A, and showing the square tower surmounted by its anemometer.
FIG. 3.—View of the court C with the rotary-pump worked by the steam-engine *i* in the gallery behind.
FIG. 4.—Interior view of the atelier, or workshop *j*, serving for the preparation of the materials for experimental researches.
FIG. 5.—Experiment hall *k*.

[*Note of acknowledgment.*—I wish to express here my special thanks to Professor Mangon, to whom I am indebted for detailed explanations of the laboratory, and other recent favors, as well as for those received when a student in the school.]

BUDGET AND EXPENSES.

The annual credit (budget) of the school and its attached services amounts in round numbers to 300,000 francs. This sum includes the salaries of the professors and students and the total cost of material and personnel.

The greater part of the professors receive from this only small sums, when they are in addition charged with the duties of an active service.

The secretary of the school fulfills the duties of registrar and treasurer.

[*Note of acknowledgment.*—In terminating this extended report I wish to acknowledge my indebtedness to the inspector of the school, Mr. Emmery, for valuable information and documents, and to the librarian, Mr. Schwebelé, for many favors and courtesies.]

AWARD.

AWARD.—The jury of Group XVIII awarded to the school the DIPLOMA OF HONOR.

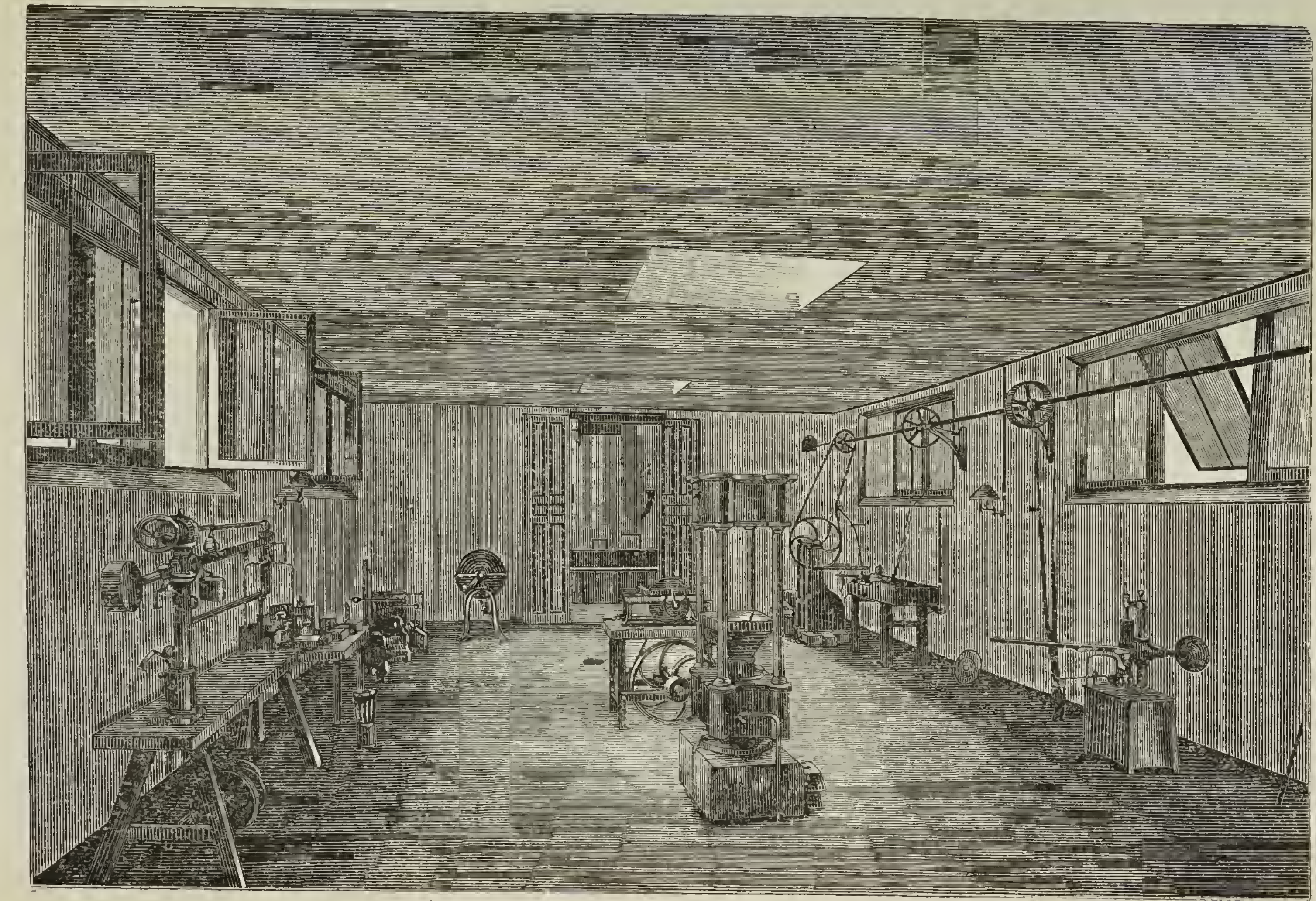


FIG. 4.—Interior of atelier or workshop, *k*.

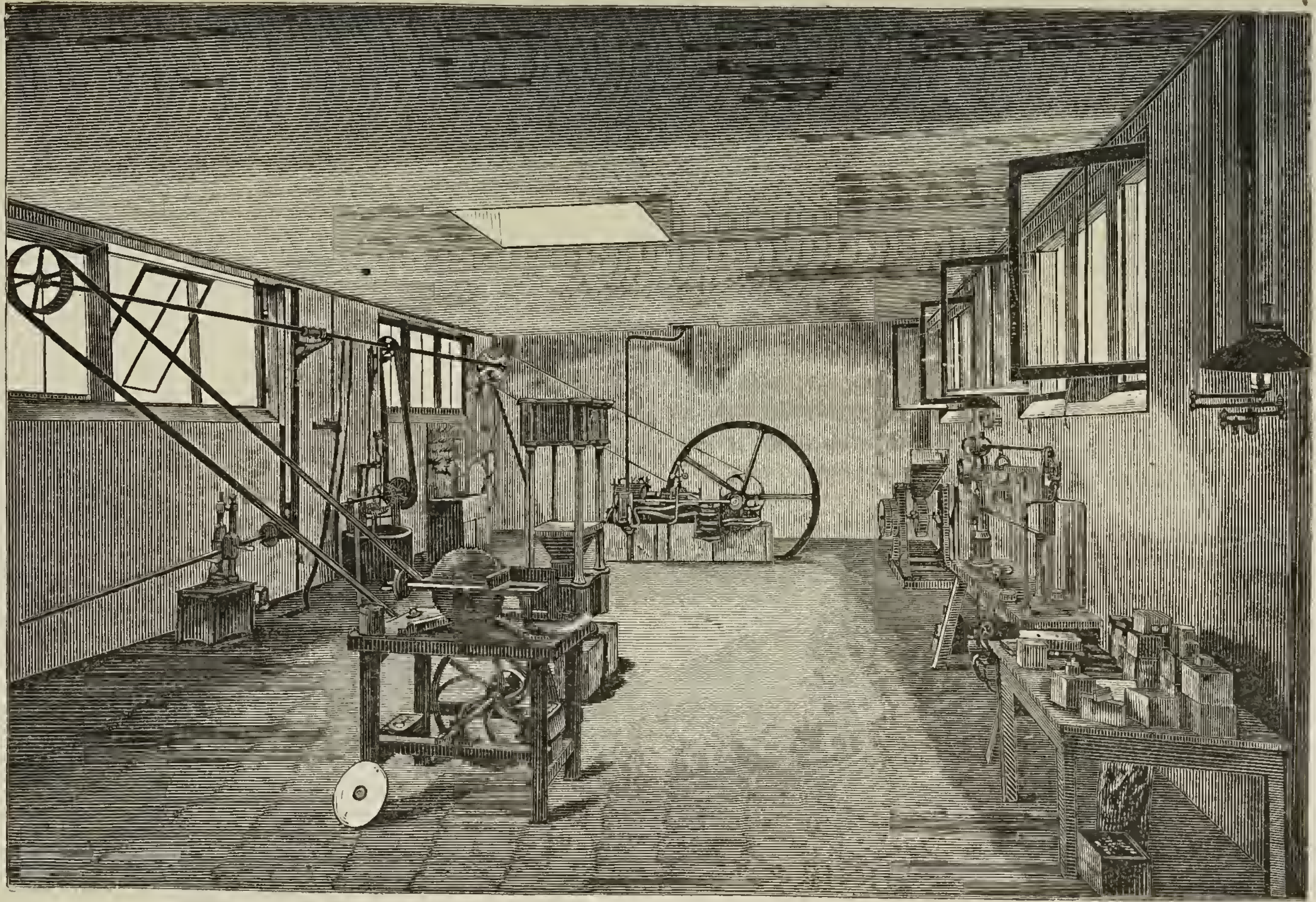


FIG. 5.—Interior of experimental room, *k*.

NOTE OF ACKNOWLEDGMENT.—I wish, in this connection, to acknowledge my indebtedness to the French minister of public works for a series of valuable drawings and documents relating to the canals and rivers of France.

PLATE A.

MOVABLE DAM ACROSS THE SEINE—GENERAL VIEW.

Plate A represents a general view of the movable dam across the Seine, at Port à l'Anglais, four kilometers above Paris.

The view is taken from below, looking up-stream. At the extreme right is the great breach in the weir, made to provide a channel for the traffic while the lock was being rebuilt. At the left of this breach is the weir, now reduced to a length of 37.90 meters, with its gates lowered. It is separated from the old pass by a stone pier three meters wide, situated in the middle of the river. At the left of the pier is the old pass, 54.70 meters wide; its gates are lowered, and as the sill is 1.10 meters below that of the weir, they are consequently submerged.

At the extreme left is the lock as it appeared during the process of reconstruction. This process consisted in lowering both the floor-chamber and the tail miter-sill a depth of one meter, and also rebuilding the side walls.

The total length of the lock is 210 meters; its width, 16 meters, allows it to contain a double line of boats. A depth of two meters is retained upon the tail miter-sill from the next dam below, at Suresnes. The head miter-sill is unchanged, so that the lift-wall is one meter in height.

At the side of the lock are seen the pile-drivers and pumping-boats used in rebuilding

PLATE B.

MOVABLE DAM AT PORT À L'ANGLAIS—NEW PASS, WEIR, AND OLD PASS.

Plate B represents the movable dam at Port à l'Anglais, as seen from the shore on the right, looking down-stream.

At the right is the new pass, with its iron *fermettes* and the gates. Seventeen of the *fermettes* are erect, and the eighteenth is half raised.

At the left of the pass is the weir, with its twenty-seven automatic *hausses*, or falling-gates. In front of these is a service-bridge, carrying a lifting-windlass. The sill of the weir is 1.80 meters above that of the pass.

At the left of the weir is the old pass; its sill is 1.10 meters below that of the weir; the gates are down; they can be raised by means of a maneuvering-boat, and lowered by a capstan and talon-bar.

Still farther to the left are the tail-walls of the lock; and beyond, the lockman's house.

PLATE C.

NAVIGABLE PASS AT PORT À L'ANGLAIS.

Plate C represents the new navigable pass at Port à l'Anglais, as seen from below, looking up-stream.

The opening of the pass is 28.70 meters. It has 26 *hausses* and as many *fermettes.*

The draught on the sill in the lower bay usually exceeds 0.70 meter; that in the upper bay, maintained by the gates, is 3.70 meters; the strength of all the parts of the structure has been calculated on a supposition that a sheet of water 0.40 meter thick flowed over the tops of the *hausses;* that is, it has been calculated to resist a pressure due to a difference of level of 3.80 meters between the two bays.

Angle of the gate with the horizon is	80°
Angle of the abutment-prop with the horizon is	37°

	Kilograms.
Total pressure on a *hausse* is	9,300
Total pressure on the head of the horse	7,422
Compression of the abutment-prop	9,051
Tension on the horse	2,920
Bending moment of the *hausse*	2,746

PLATE D.

DETAILS OF THE NAVIGABLE PASS AT PORT À L'ANGLAIS.

Plate D represents a portion of the new pass as seen from below, looking up-stream, with the gates and *fermettes* in various positions.

Horses.—Each horse is in the form of a trapezoid, 1.90 meters high, 0.76 wide at the base, 0.50 at the top. It weighs 190 kilograms. The abutment-prop weighs 270 kilograms, and is calculated to resist a compressive stress of 9,000 kilograms.

Sill.—The sill is composed of three pieces: the first holds the journal-boxes of the horses; the second receives the pressure of the horses, and the third the shock of the *hausses* when they are first raised.

Fermettes.—Each *fermette* has the form of a trapezoid, 4.80 meters high. The upper base, which supports the flooring, is 1.20 meters long; the lower base, or axle, is 3.10 long; the up-stream post is 4.80 meters high; the down-stream post is inclined at 5 vertical to 2 base, and the brace 3 vertical to 2 base.

Beside the brace, the *fermette* is stiffened by three horizontal transoms and a fourth inclined, and forming with the brace a Saint Andrew's cross. Except the lower axle, which is a cylinder 0.08 meter in diameter, each piece of the *fermette* is of U-iron, an economical arrangement, as equal weights of U-iron have a much greater transverse strength than square or even T iron, since the material is farther from the neutral axis.

The joints are easily made, and the weight per running meter is less than that employed in the construction of M. Poirée's smaller *fermettes.*

All the joints are stiffened by gussets of plate-iron 0.007 meter thick, and in addition by wrought-iron knees at the four corners of the trapezoid.

The knees of the upper angles have gudgeons, which receive the connecting-rails upon which the maneuvering-windlass rolls, and also the link-catches that hold the chains of the *hausses.*

Strength of the fermettes.—Each *fermette* has been arranged so as to withstand from ts cap a pull from the maneuvering-chain of 3,000 kilograms under an angle of 45°.

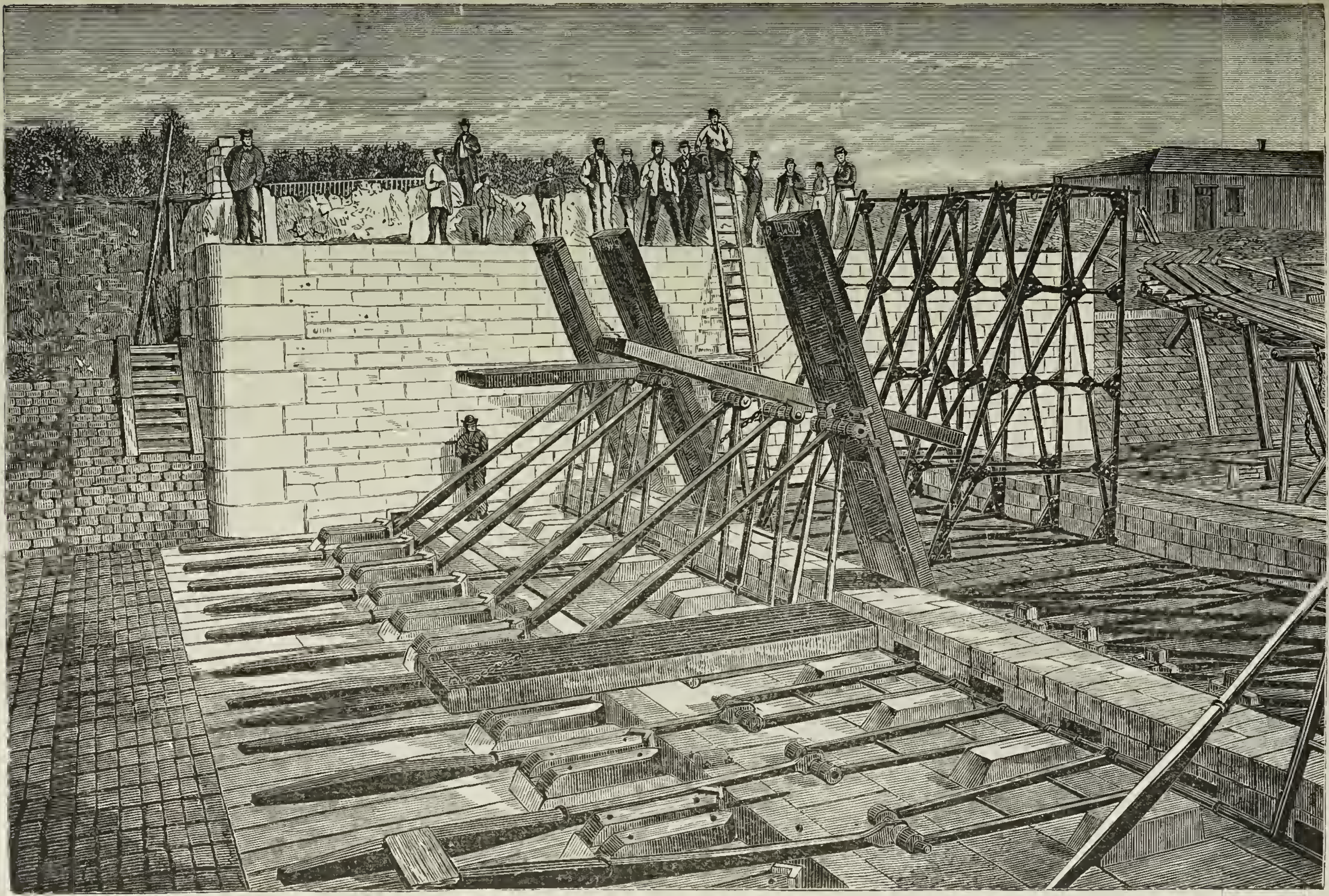


PLATE D.—Movable dam across the Seine. A portion of the new pass as seen from below.

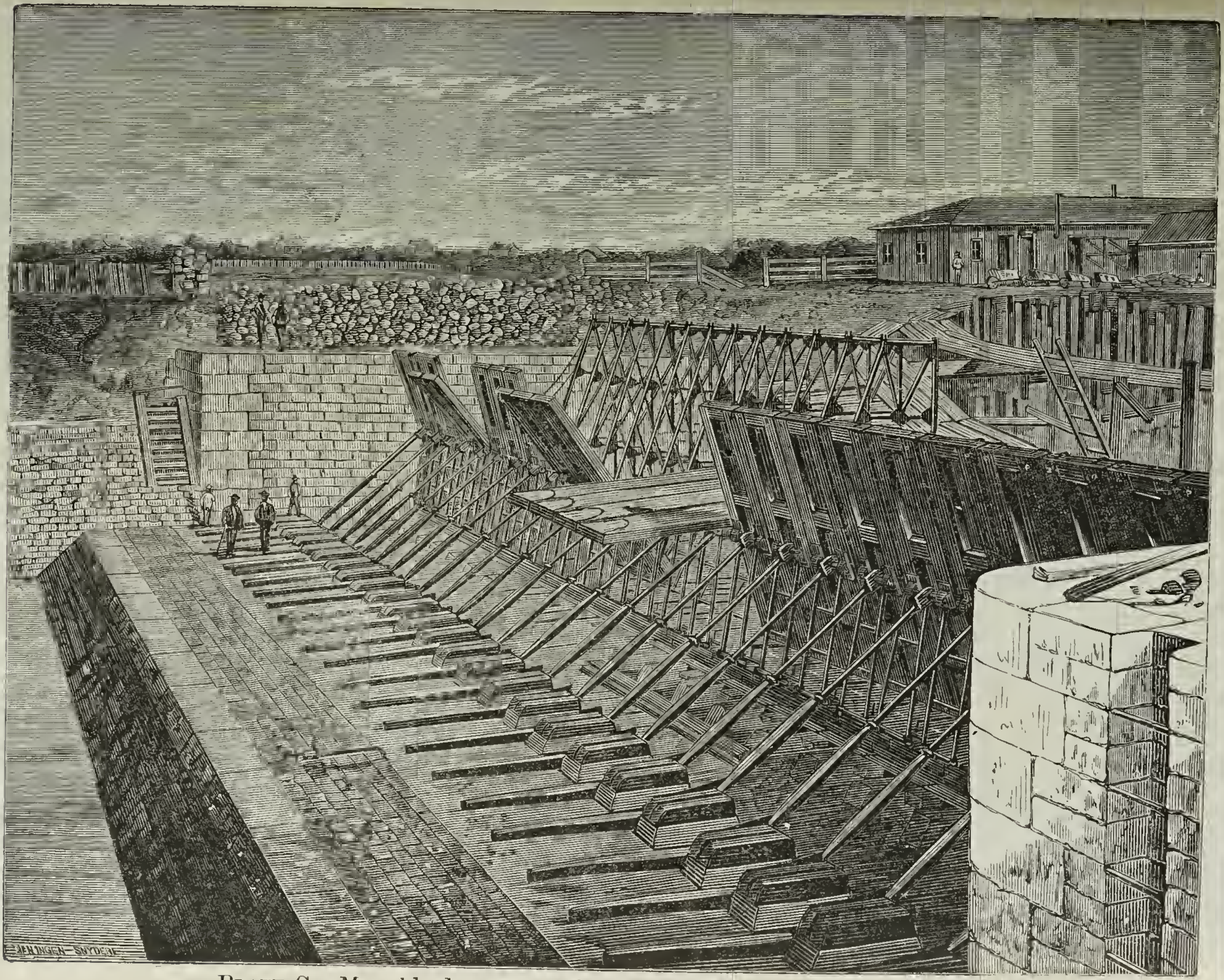


PLATE C.—Movable dam across the Seine. New pass seen from below

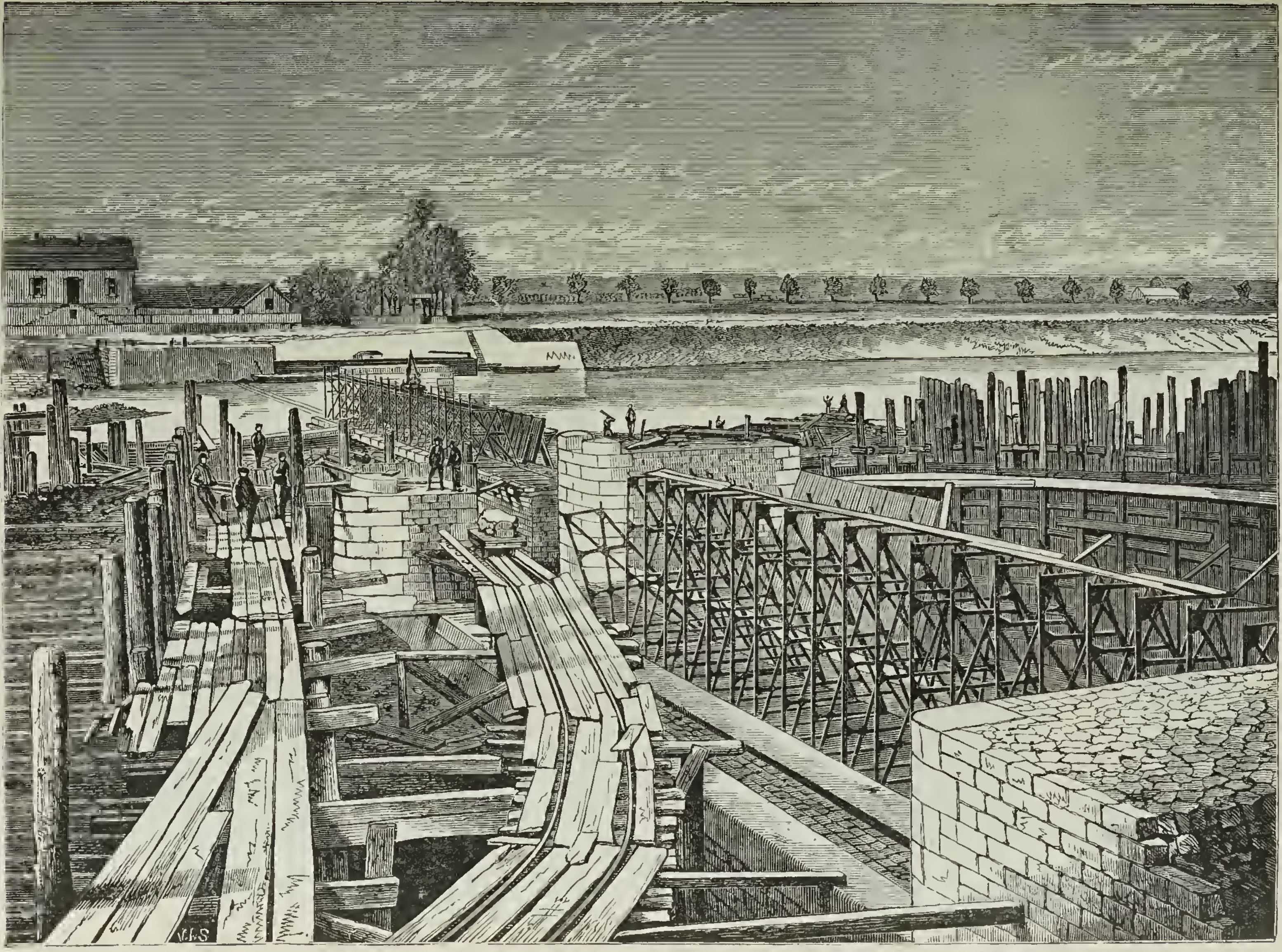


PLATE B.—Movable dam across the Seine. New pass, overfall, and old pass.

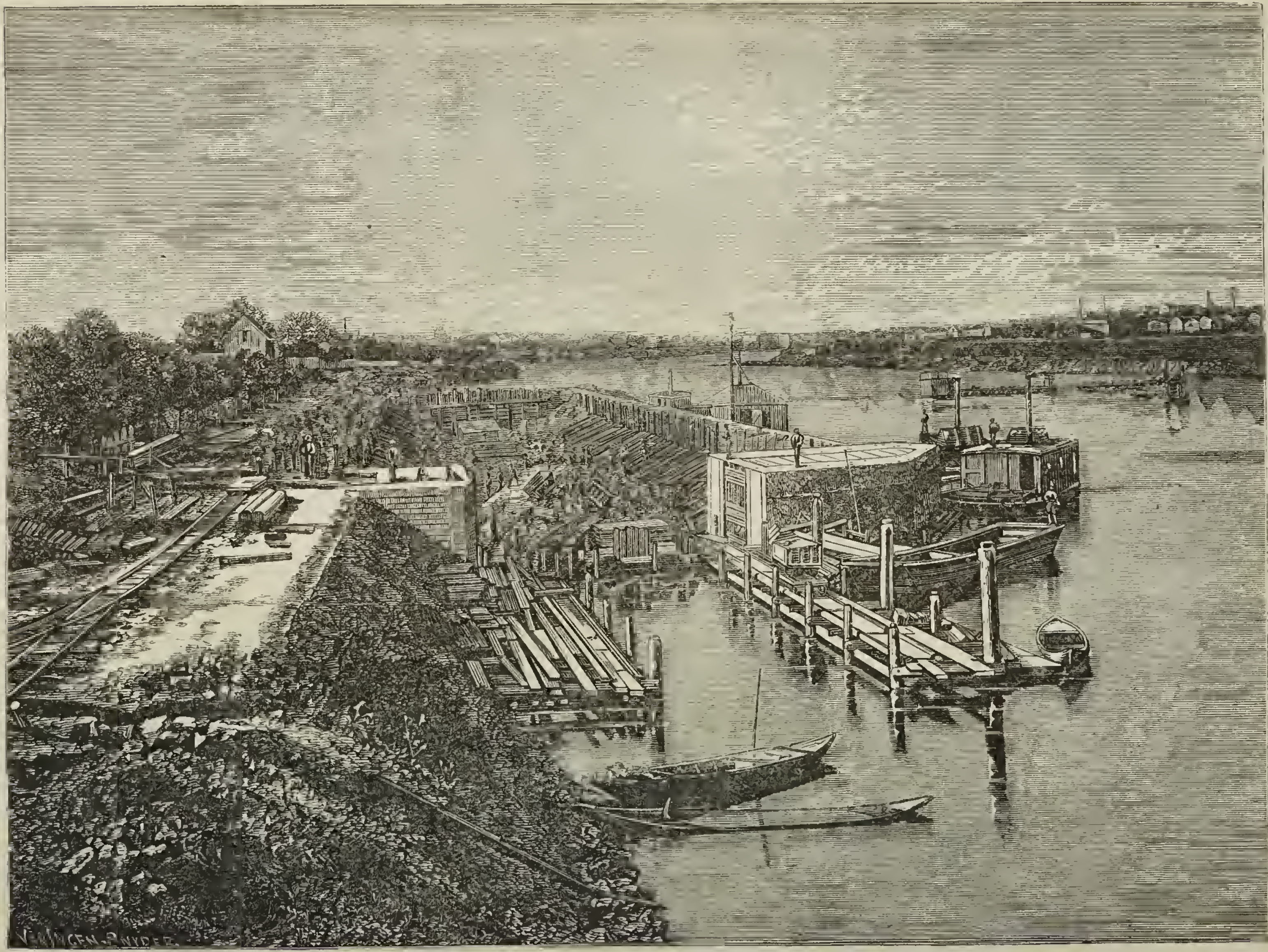


PLATE A.—Movable dam across the Seine. General view.

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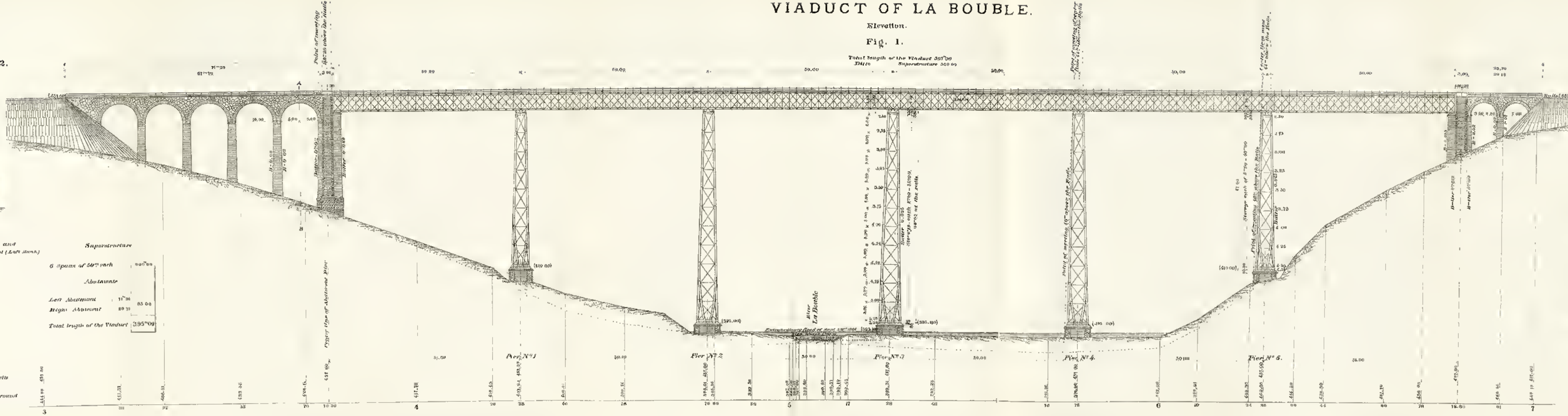
COMMENTRY TO CANNAT.

VIADUCT OF LA BOUBLE.

Elevation.

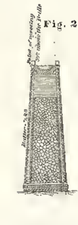
Fig. 1.



Superstructure

6 Spans of 50m each		300m00
Abutments		
Left Abutment	11m36	95.00
Right Abutment	29.21	
Total length of the Viaduct		395m00

Fig. 2.



Section of an Arch at AB and elevation of the Abutment (Left Bank.)

Sections – transverse.

Fig. 3.

A great Pier.

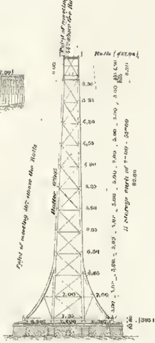


Fig. 4.

A small Pier.

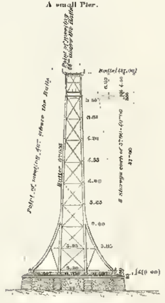
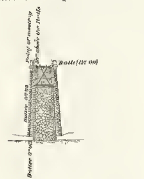


Fig. 7.

Elevation of the right Abutment.



Plans.

Scale: 0.00375

Fig. 5.

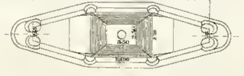
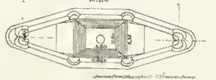


Fig. 6.



Orleans Railroad.

VIADUCT OF LA BOUBLE.

IRON PIERS.

Commentry to Gannat.

SCALES { General Plans . . . 0.022
Details. 0.022

Fig. 1.

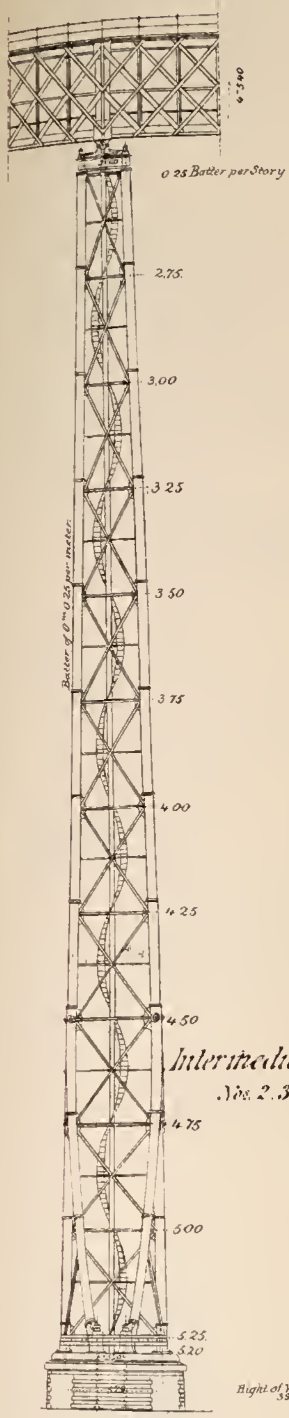
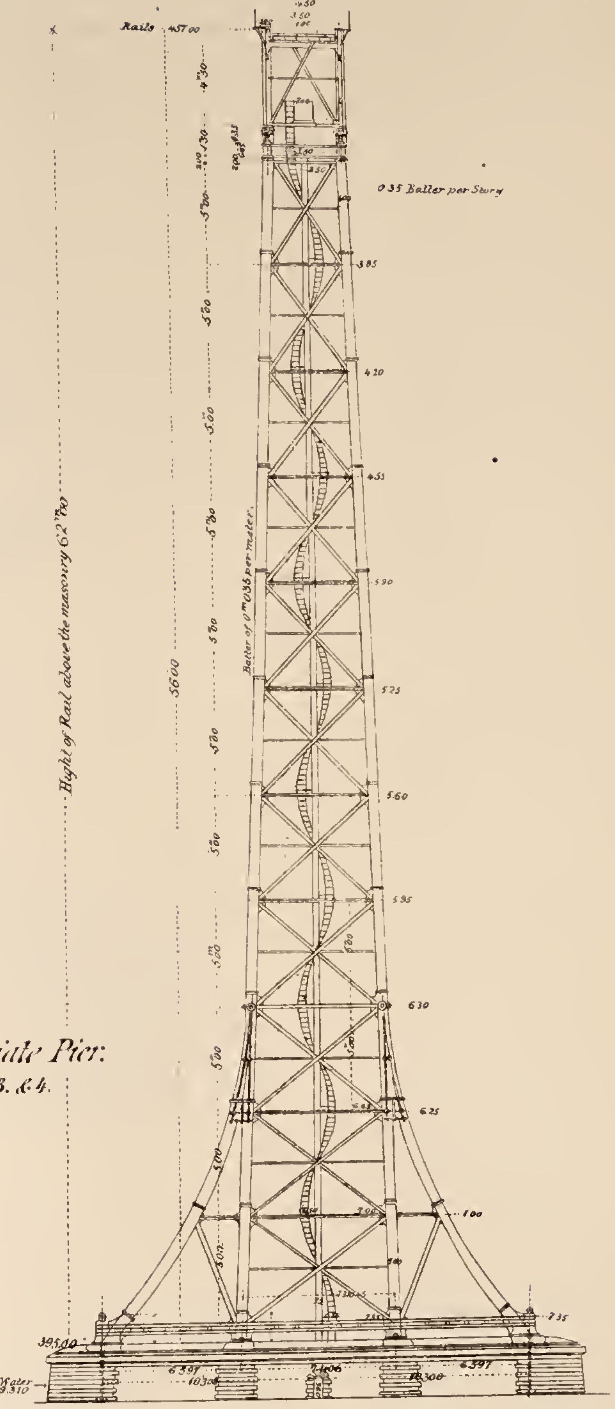


Fig. 2.



Intermediate Pier.
Nos. 2. 3. & 4.

Fig. 3.

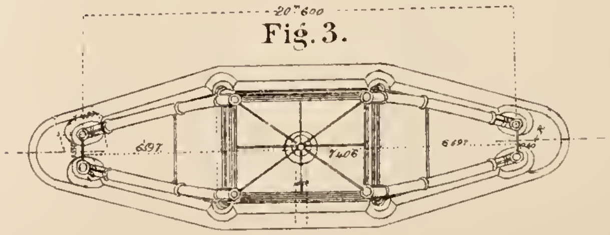


Fig. 4.

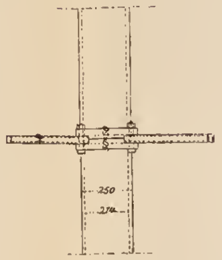


Fig. 5.

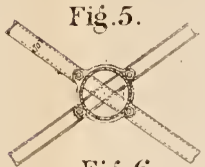


Fig. 6.

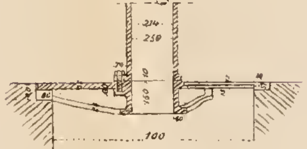


Fig. 7.

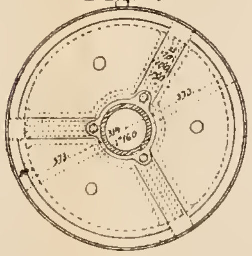


Fig. 8.

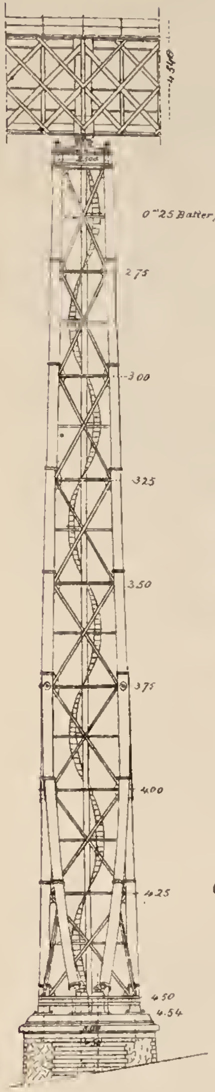


Fig. 9.

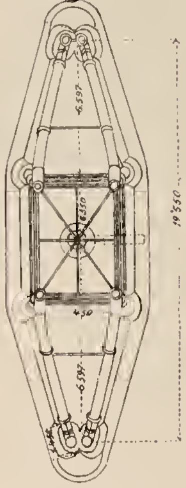
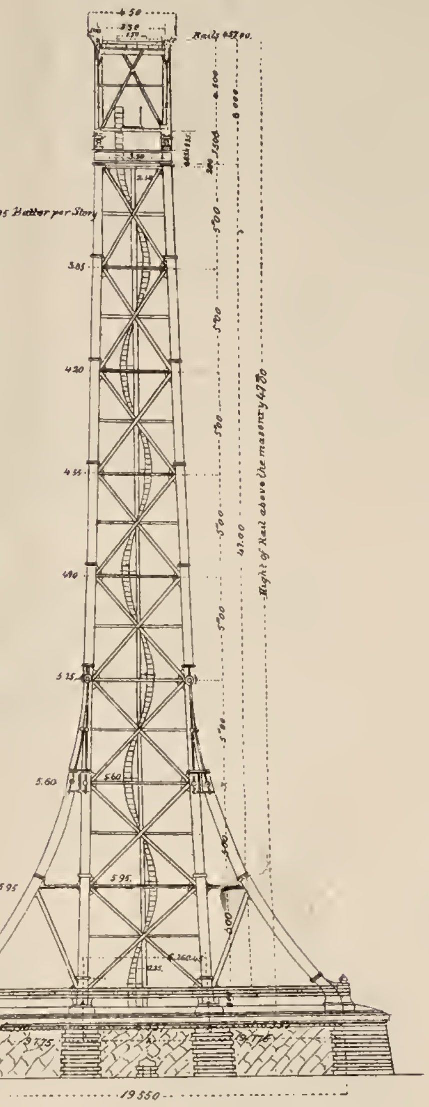


Fig. 17.



Outside Pier.
Nos. 1 & 5.

Fig. 10.

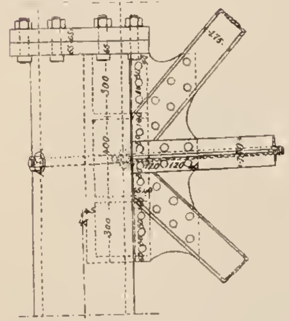


Fig. 11.

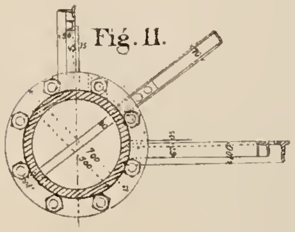


Fig. 12.

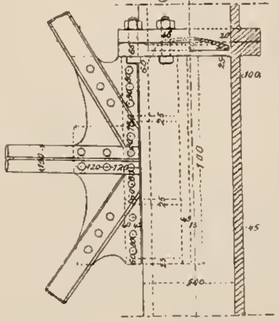


Fig. 13.

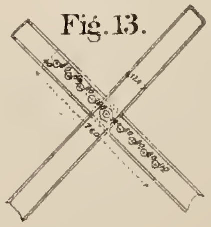


Fig. 14.

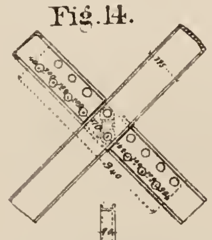


Fig. 15.

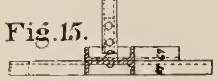
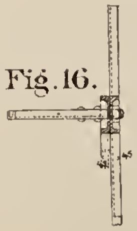


Fig. 16.



American Photo-Lithographic Co. N.Y. (Osborne's Process.)

Orleans Railroad.

Commentry to Gannat.

VIADUCT OF LA BOUBLE.

FOUNDATION OF PIER Nº 3.

SCALE { *Elevation and Plan . . . . 0m $\frac{1}{120}$*
{ *Profile of the Coping. . . . . 0m $\frac{1}{24}$*

Fig. I. *Transverse Elevation.*

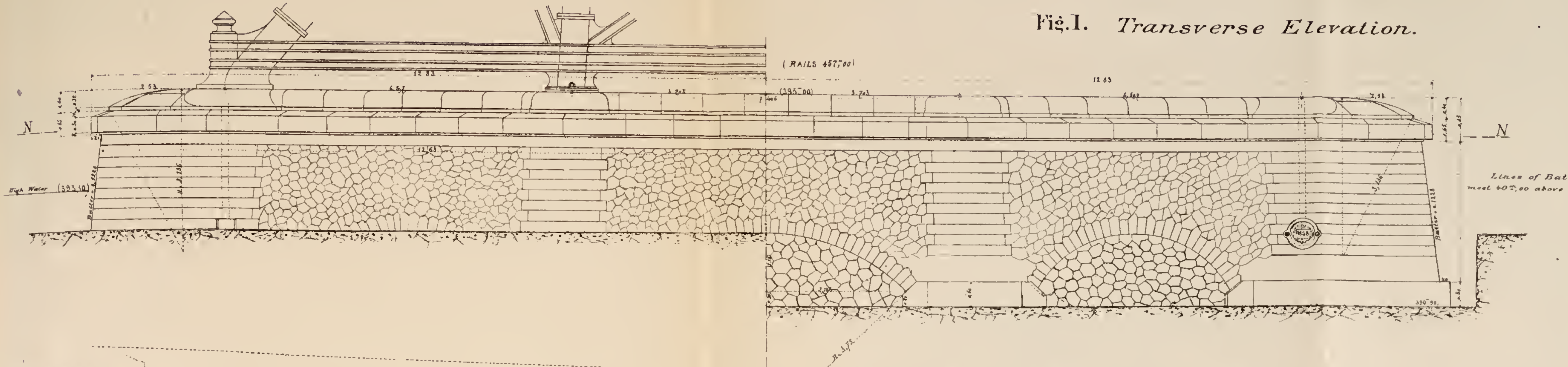
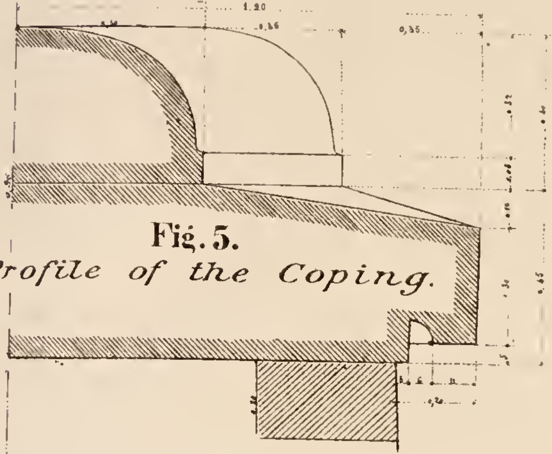


Fig. 5. *Profile of the Coping.*



Elevation of the face.

Fig. 4.

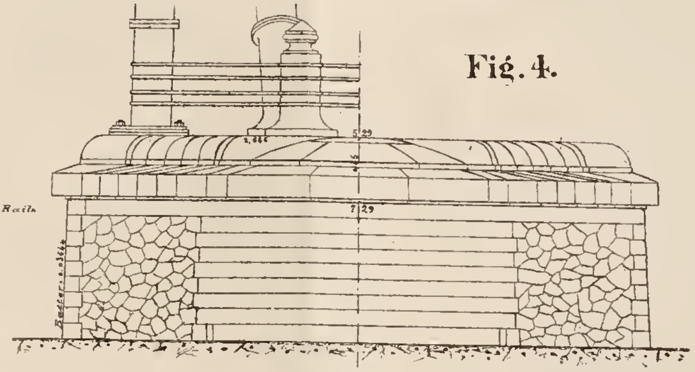


Fig. 2. *Half Plan above the Coping.*

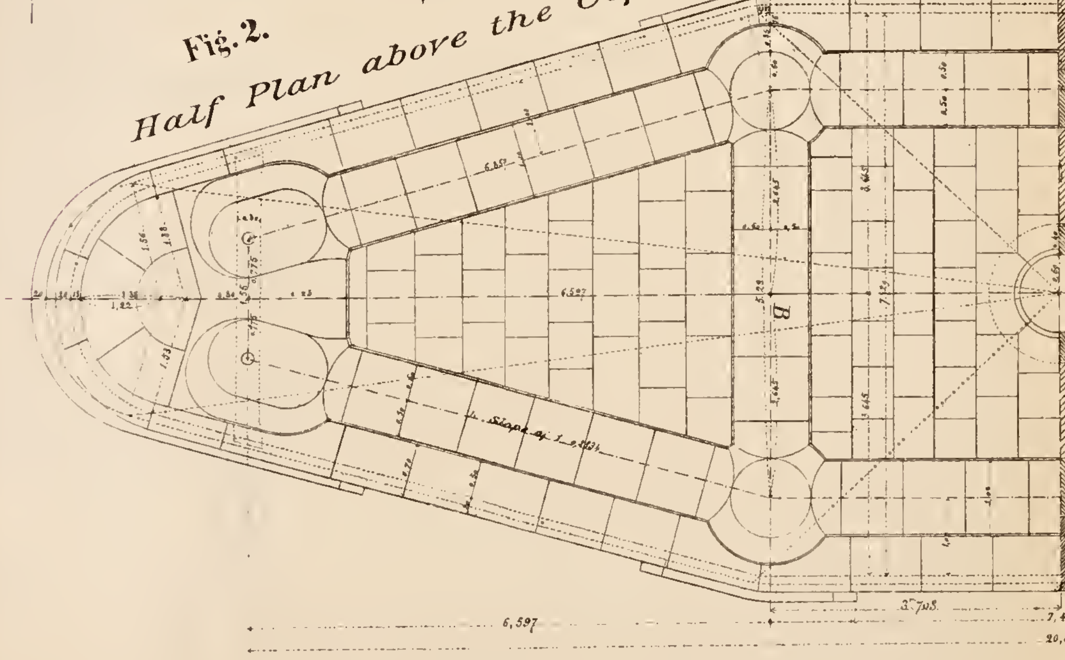
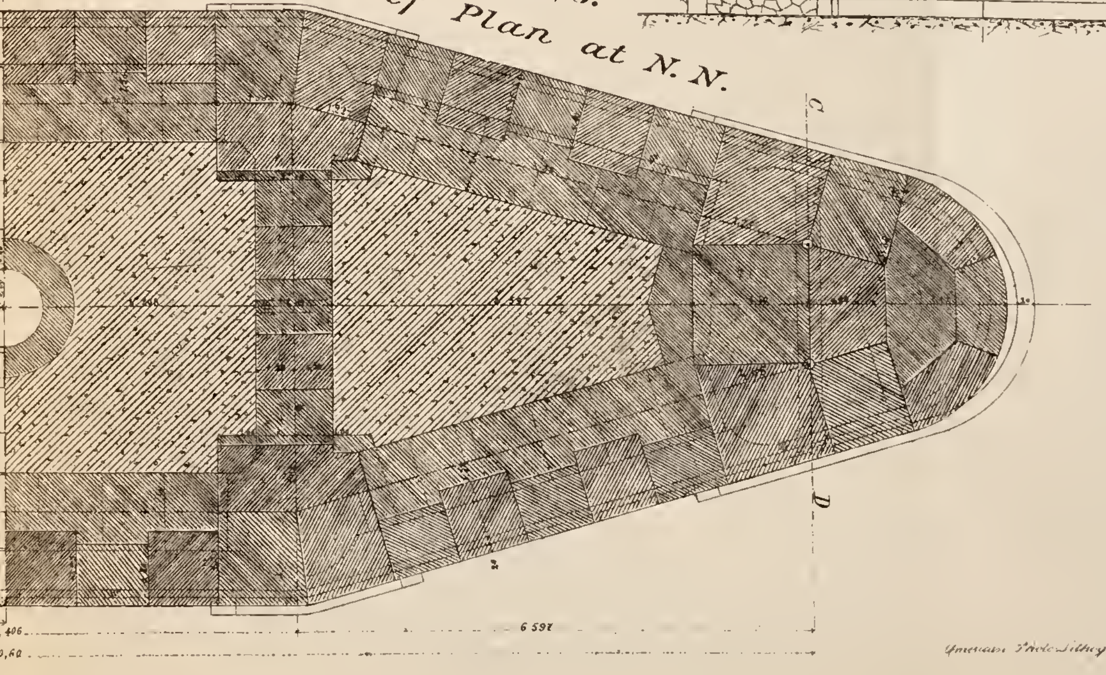


Fig. 3. *Half Plan at N. N.*



American Photo-Lithographic Co. N.Y. (Osborne's Process)

VIADUCT OF LA BOUBLE.

Orleans Railroad.

Fig. 1.

Elevation at an Abutment.

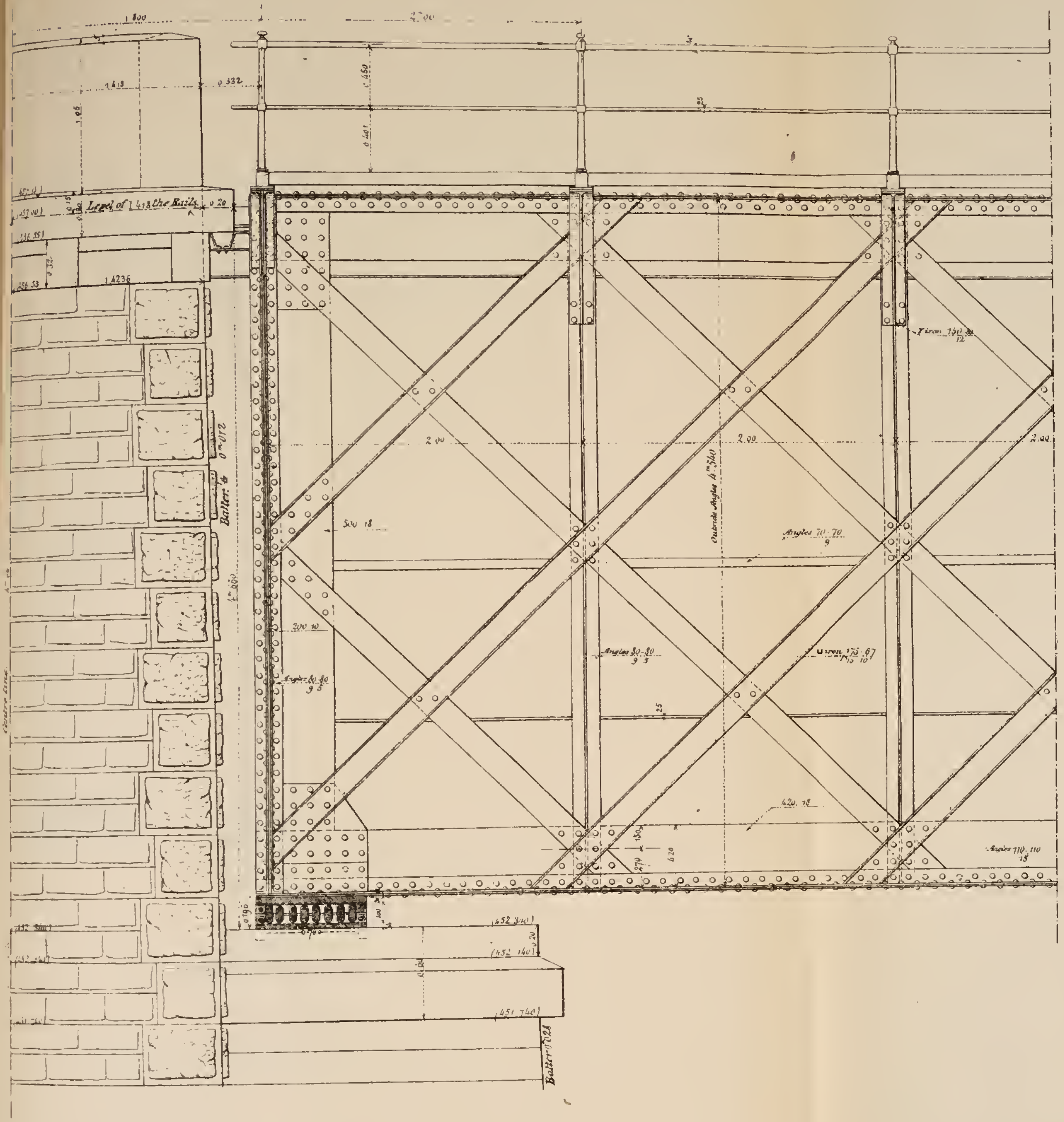
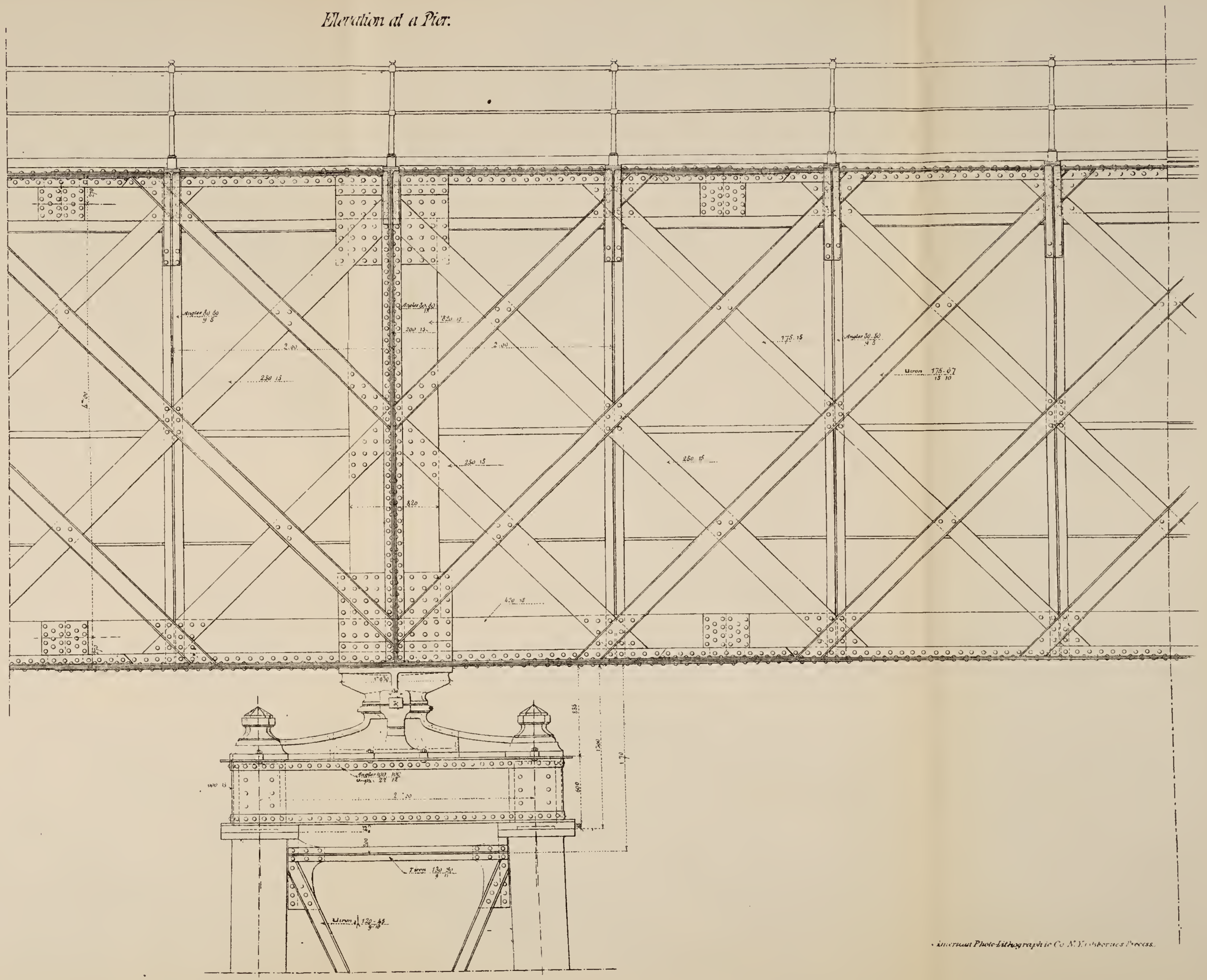


Fig. 2.

Elevation at a Pier.



American Photo-Lithographic Co. N.Y. (Osborne's Process.)

COMMENTRY TO GANNAT.

Fig. 1.

Longitudinal Section.

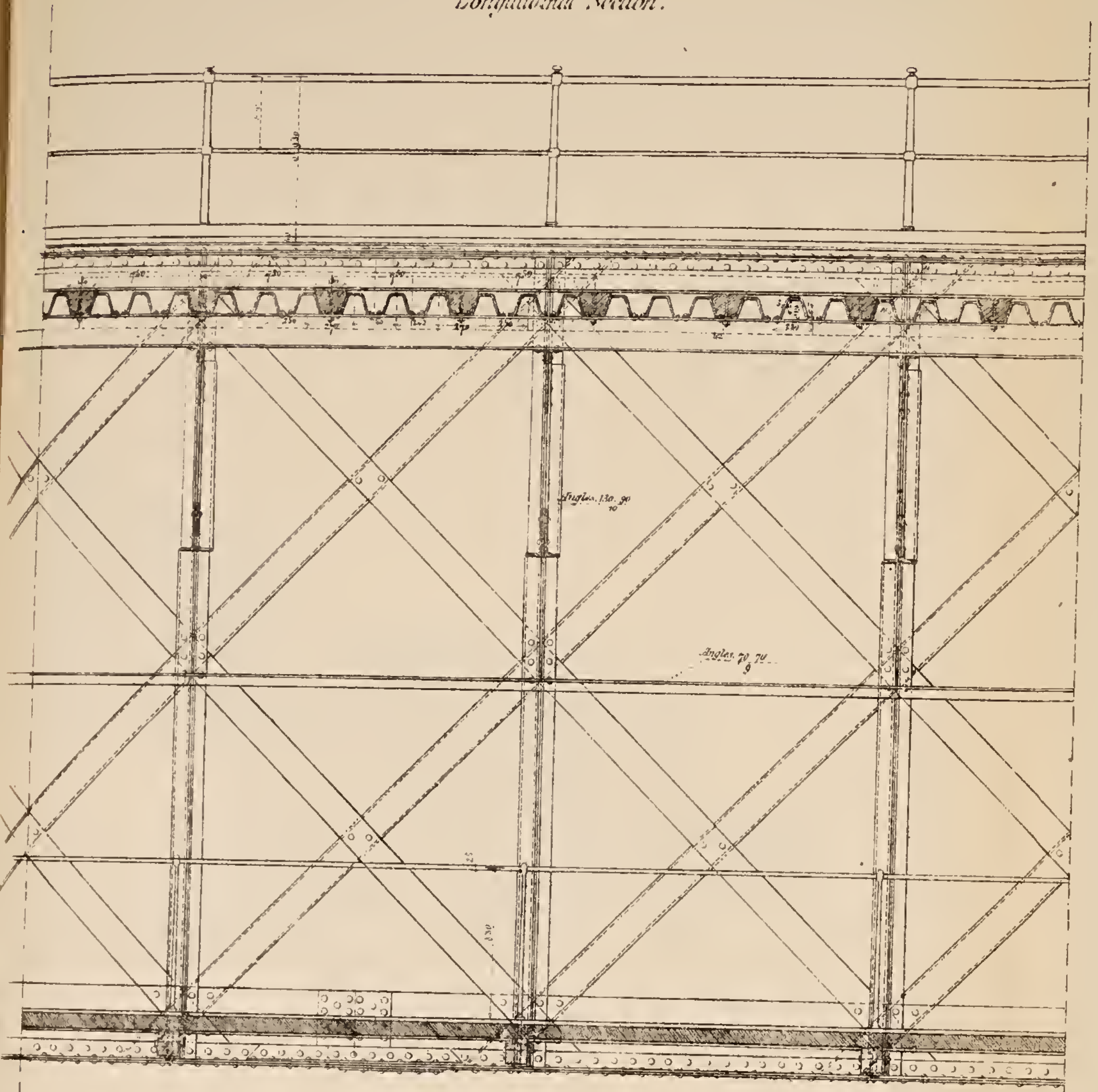


Fig. 2.

Transverse Section.

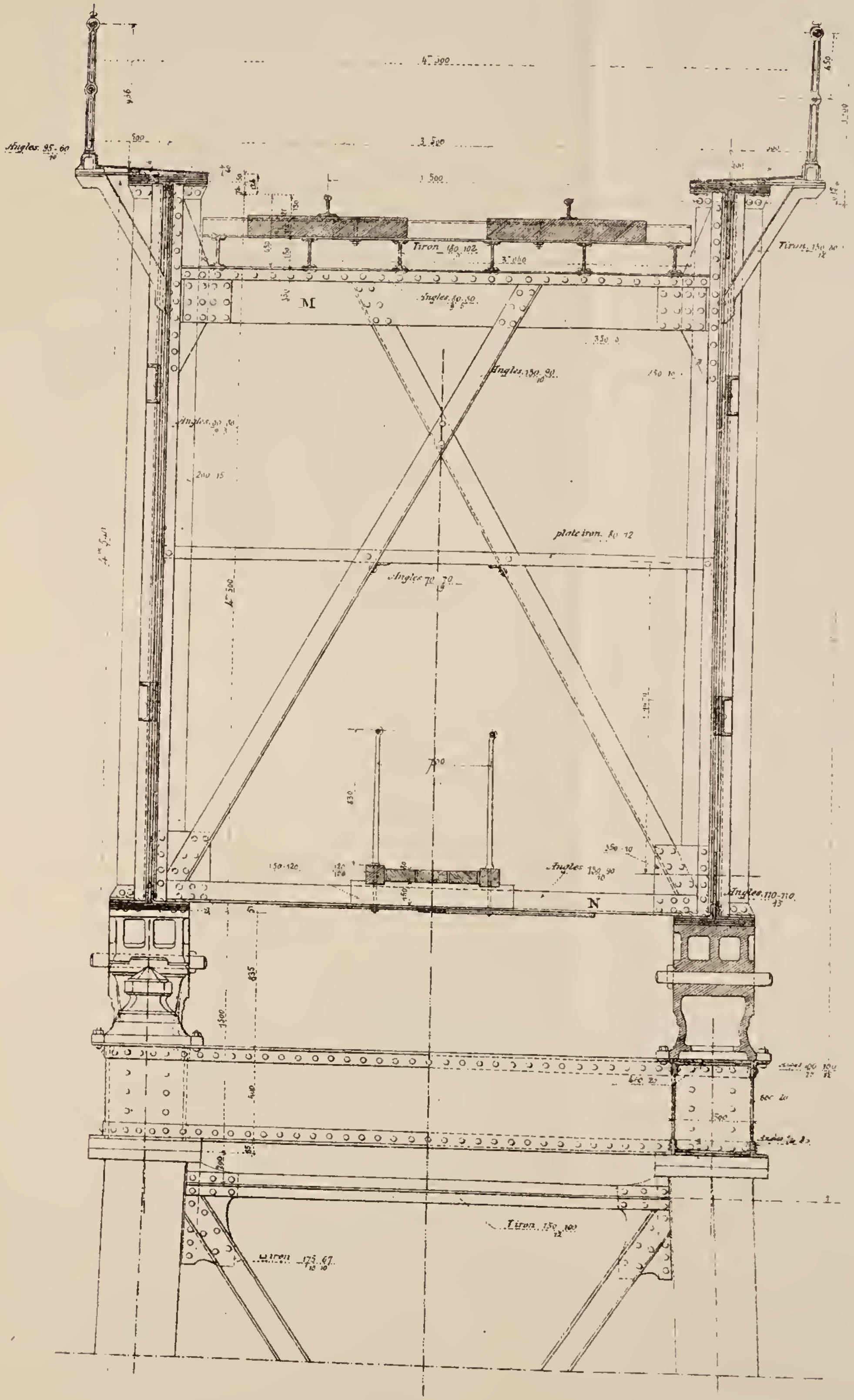


Fig. 3.

Arrangement of Supports on outside Piers.

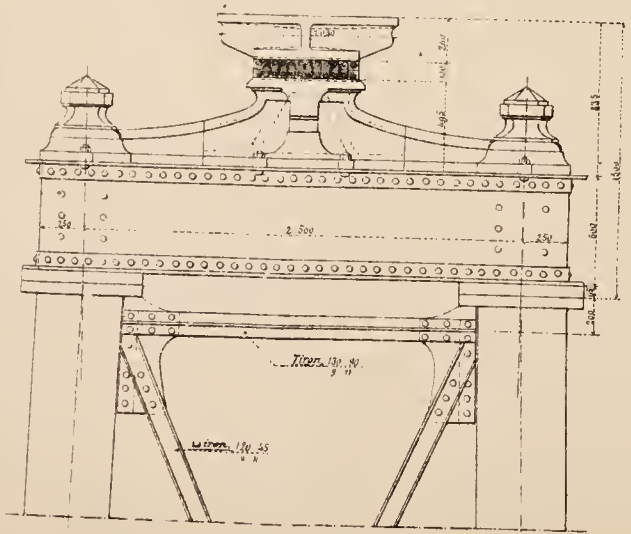
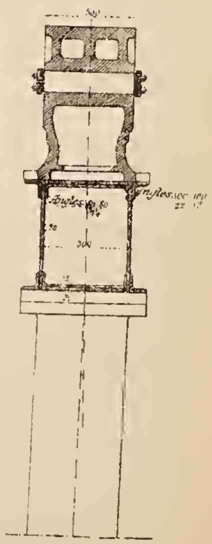


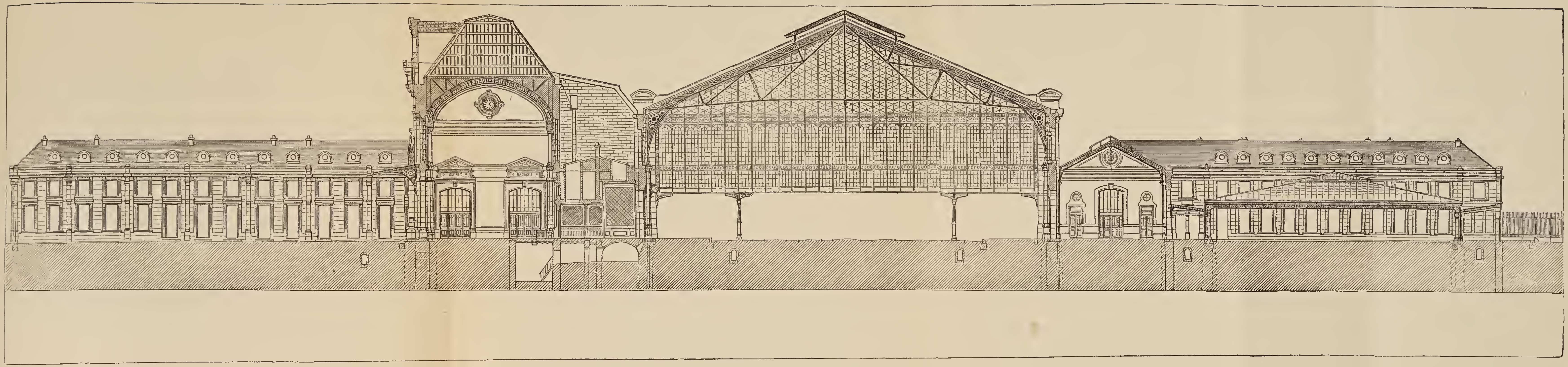
Fig. 4.



American Photo-Lithographic Co. N.Y. (Osborne's Process)

NEW RAILWAY TERMINUS AT PARIS.

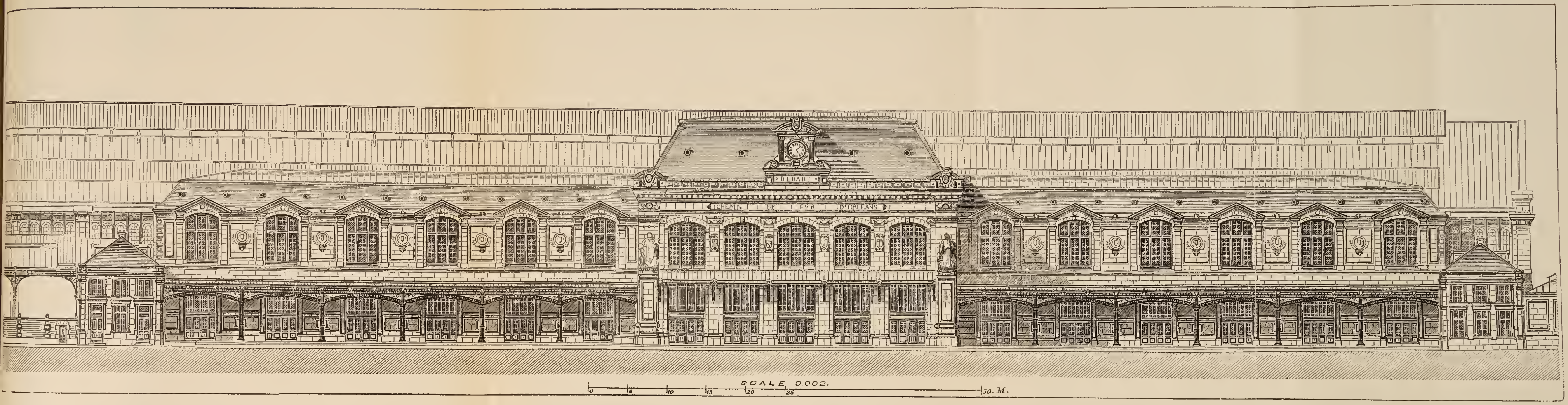
PLATE VI—A.



A Fig. I—Transverse section.

NEW RAILWAY TERMINUS AT PARIS.

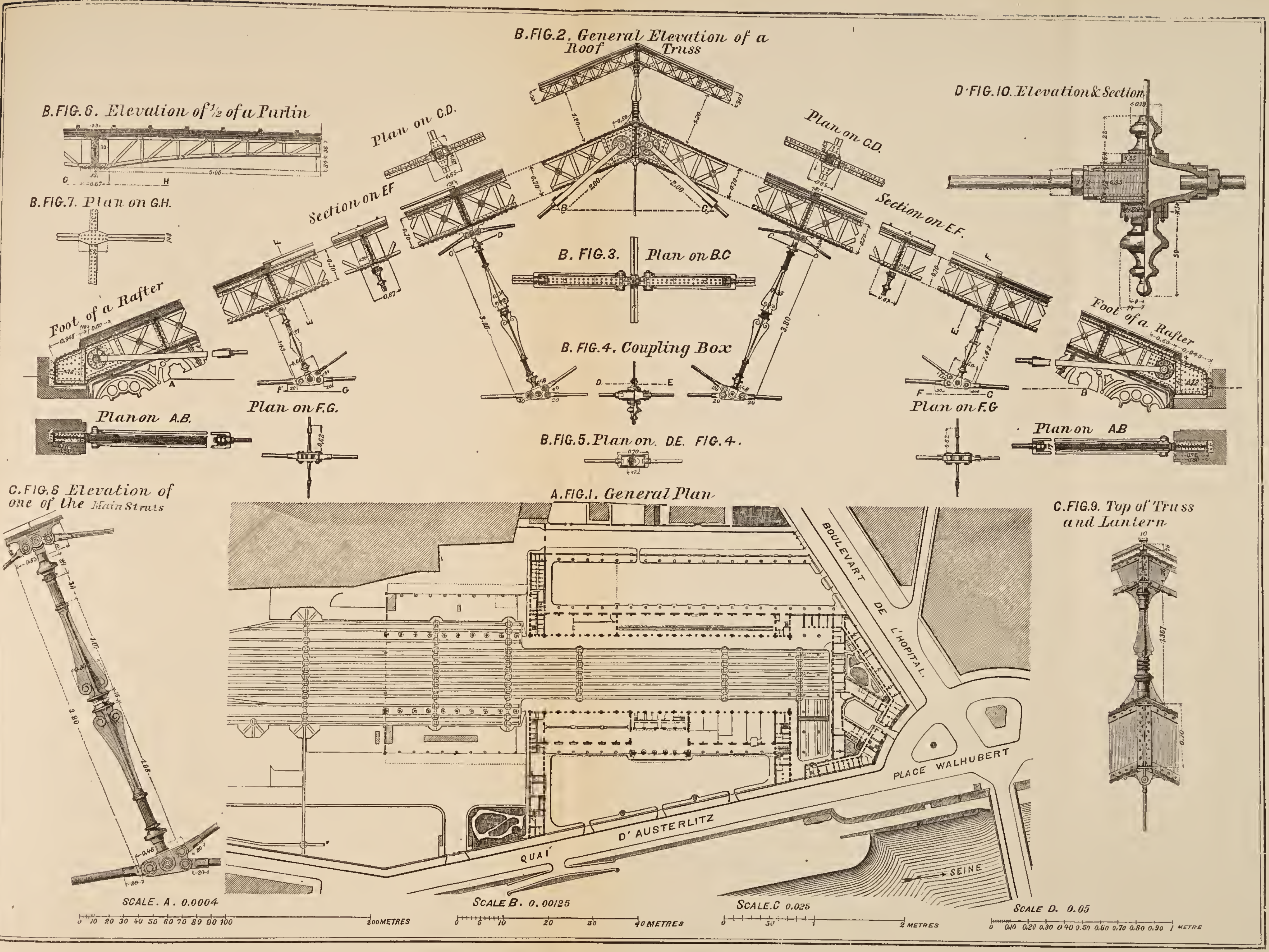
PLATE VI—B.



A Fig. II.—Façade facing the Quai d'Austerlitz.

NEW PASSENGER-STATION, ORLEANS RAILROAD, PARIS.

PLATE VII.



B.FIG.2. General Elevation of a Roof Truss

B.FIG.3. Plan on B.C

B.FIG.4. Coupling Box

B.FIG.5. Plan on DE. FIG.4.

B.FIG.6. Elevation of ½ of a Purlin

B.FIG.7. Plan on G.H.

D·FIG.10. Elevation & Section

C.FIG.8 Elevation of one of the Main Struts

A.FIG.1. General Plan

C.FIG.9. Top of Truss and Lantern

ORLEANS RAILROAD.

Station at Paris.

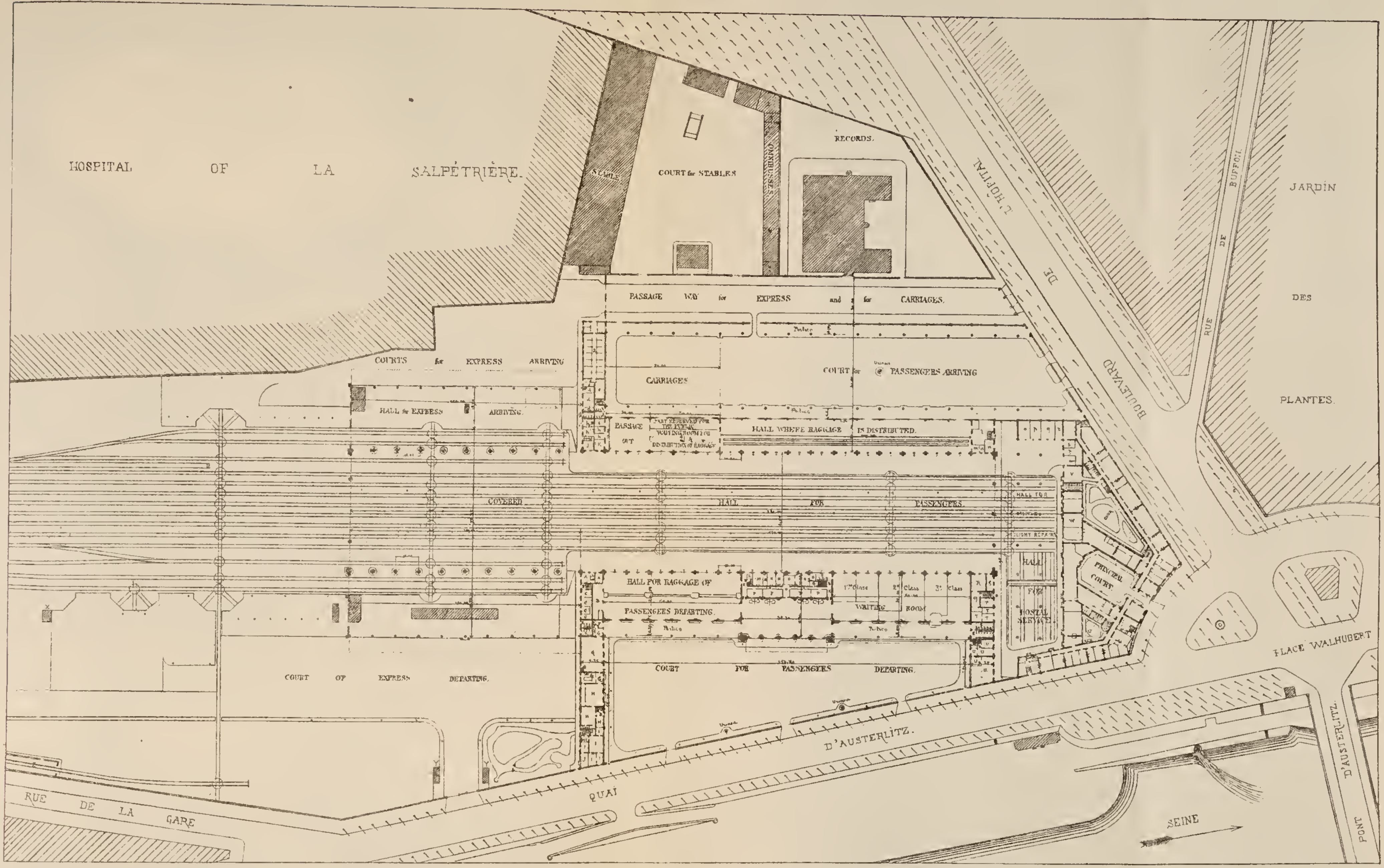
Vienna Exhibition 1873.

Pl. VIII.

GENERAL PLAN.

Scale 0.0005 mil.

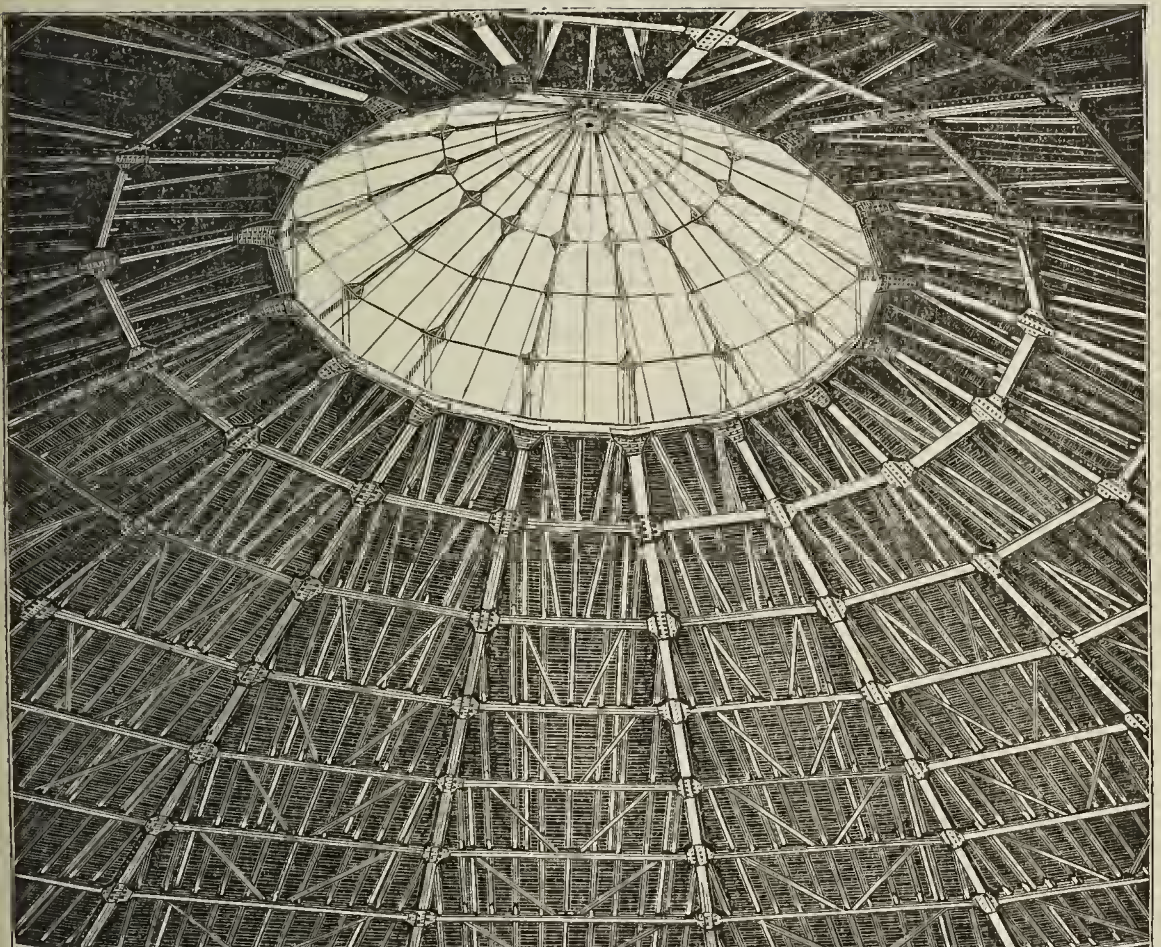
Civil Engineering etc.


HOSPITAL OF LA SALPÊTRIÈRE.
STABLE
COURT for STABLES
OMNIBUSES
RECORDS.
PASSAGE WAY for EXPRESS and for CARRIAGES.
COURTS for EXPRESS ARRIVING
CARRIAGES
COURT for PASSENGERS ARRIVING
HALL for EXPRESS ARRIVING
PASSAGE OUT
HALL WHERE BAGGAGE IS DISTRIBUTED.
COVERED HALL FOR PASSENGERS.
HALL FOR BAGGAGE OF PASSENGERS DEPARTING.
1st Class 2d Class 3d Class WAITING ROOM
HALL FOR POSTAL SERVICE
PRINCIPAL COURT
COURT OF EXPRESS DEPARTING.
COURT FOR PASSENGERS DEPARTING.
BOULEVARD DE L'HOPITAL
RUE DE BUFFON
JARDIN DES PLANTES.
PLACE WALHUBERT
QUAI D'AUSTERLITZ.
RUE DE LA GARE
SEINE
PONT D'AUSTERLITZ.

American Photo-Lithographic Co. N.Y. (Osborne's Process)

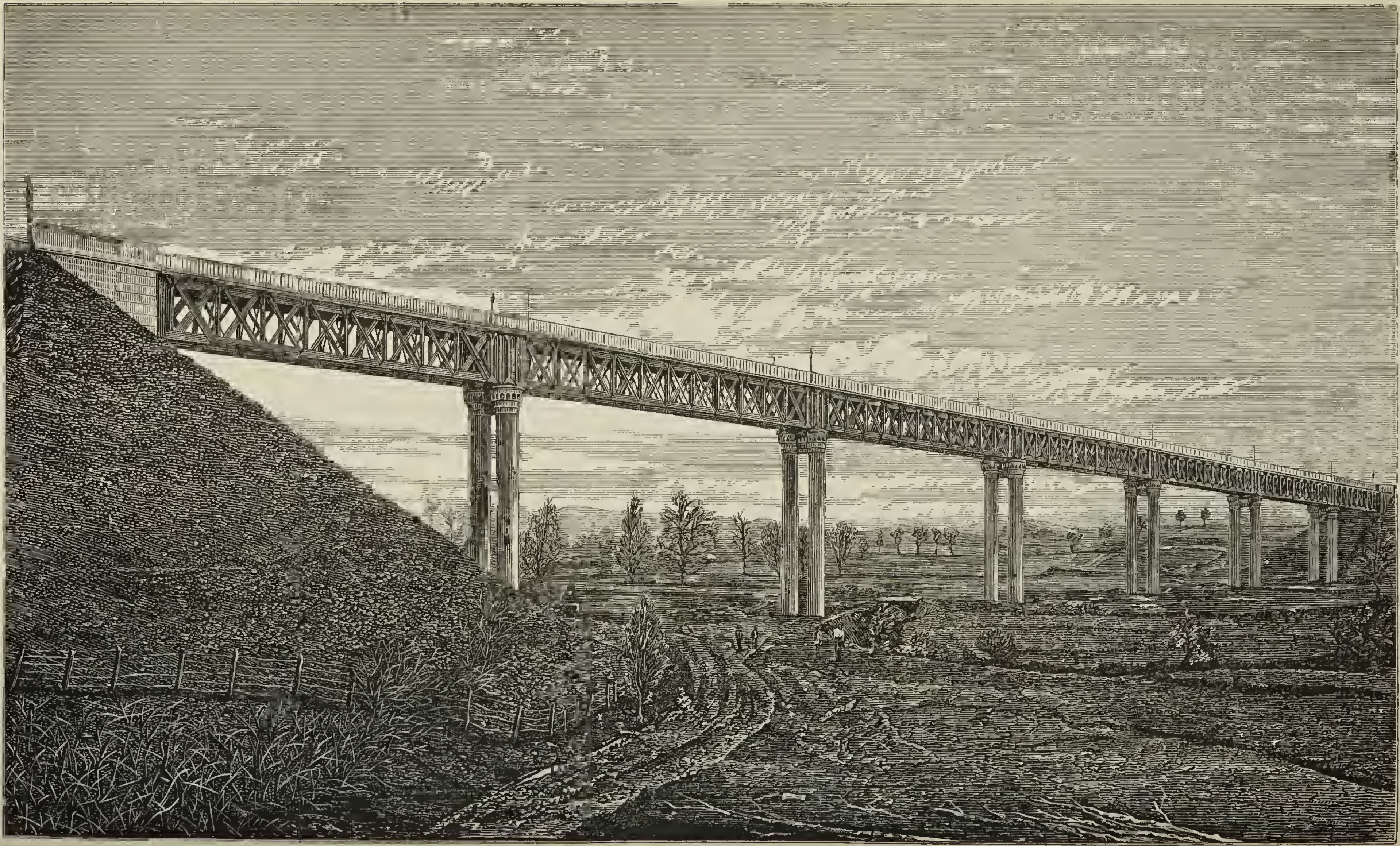
LEGEND.

Departure.				Arrival.				
A.A.A.	*Station Master.*	N.N.	*Commissary of Administration*	a.	*Expres Offices.*	n.n.	*Lamp Room.*	
BBBBBB	*Stair Cases.*	O.O.O.O.	*Service of the Emperor*	b		o.	*Forge.*	*Small repair Service.*
C.C.C.C.	*Medical Service.*	P.P.P.P.	*Ticket Offices*	c.	*Passage.*	p	*Carpenter Shop.*	
D.	*Baggage.*	q.q.	*Courts*	ddddd	*Customs.*	q.	*Harness Room.*	
EEEEEEEE	*Water Closets.*	R.	*Car Heating Dept*	e.	*Police.*	r.	*Master Mechanic.*	
F.	*Supt of the Omnibus.*	S	*Lamp Room.*	f.f.f.	*Stair Cases.*	s.	*Chief of Equipage*	
G.G.G.G.	*Restaurant.*	T.T.T.T.	*Store Rooms.*	g.g.g.g.	*Water Closets.*	t.	*Tools.*	
H.H.H		U.U.U.U.U.	*Postal Service.*	h.h.h.h	*Police.*	u.	*Journal Greasers*	
I.I.I.	*Telegraph Service.*	V.	*Express Office.*	i	*Porters.*	v.	*Bags and Portfolios*	
J.J.	*Firemen.*	W.	*Baggage Special.*	j	*Asst Station Master.*	w.	*Equipment employés*	
K.K.K.K.	*Passages.*	X.	*Store Room.*	K.	*Waiting Room.*	x.	*Little repair Shop*	*Stable Service.*
L.	*Supt of the Station.*	T.Y.	*Custom House.*	l.	*Office of Lost & Found.*	y.	*Coach Lamps*	
M.M.	*Asst Station Master.*	Z.	*Imperial Car.*	m.	*Receipt Room*	z.	*Farriery*	



ROUND-HOUSE AT MONTROUGE.

PLATE X.

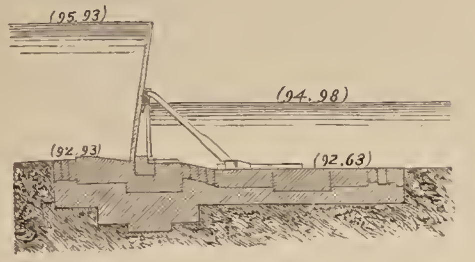


OSSE VALLEY VIADUCT.

NAVIGATION OF THE SEINE AND YONNE—PARIS TO AUXERRE.

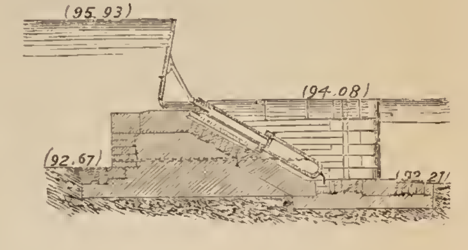
C. FIG. 3. NAVIGABLE PASS

TRANSVERSE SECTION

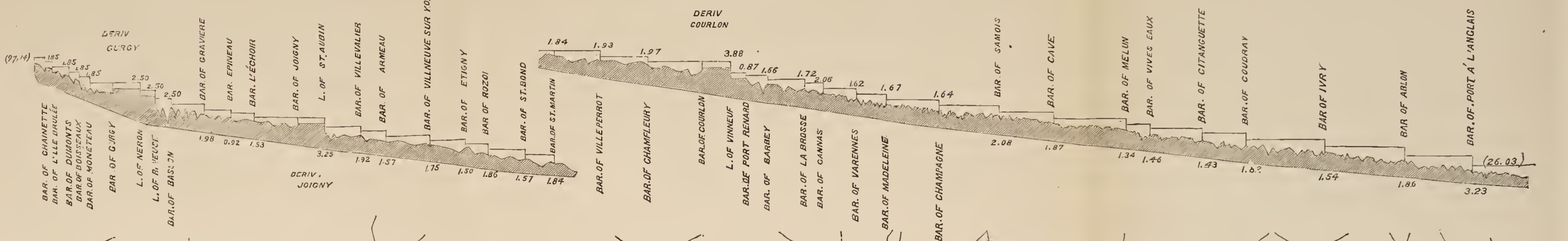


C. FIG. 4. WASTE WEIR

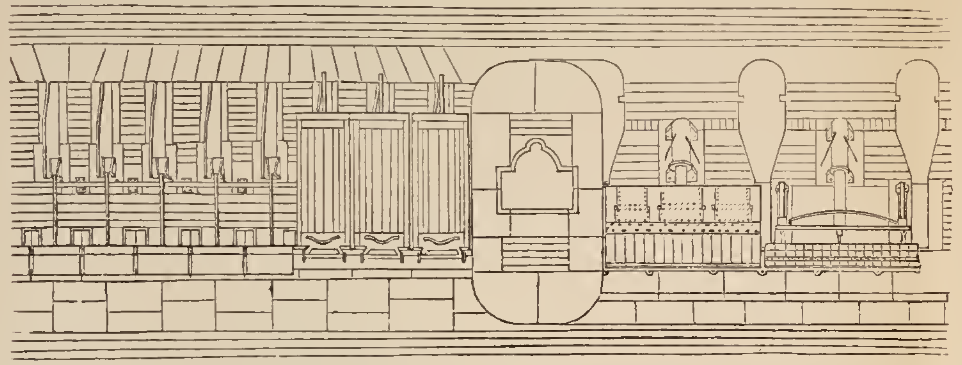
TRANSVERSE SECTION

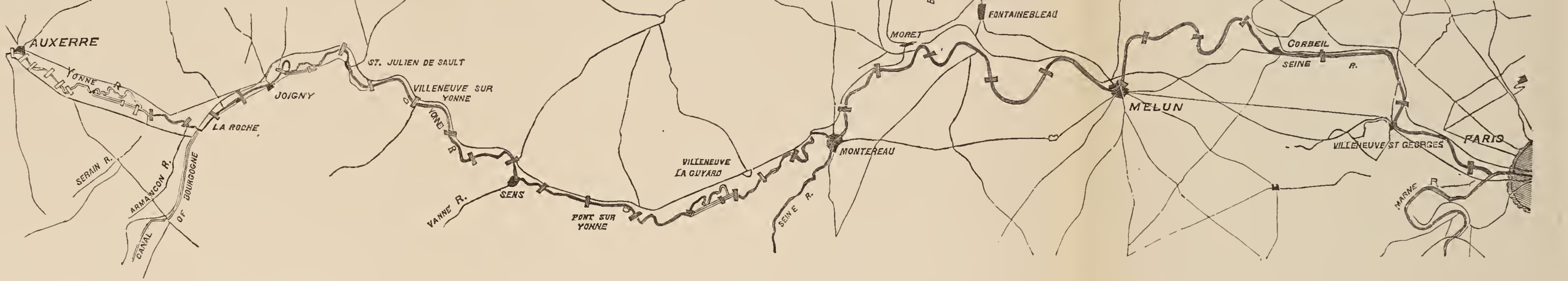


A. FIG. 1. PROFILE



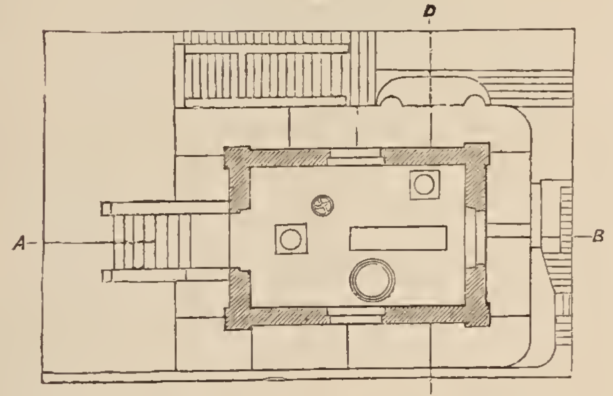
C. FIG. 5 NAVIGABLE PASS AND WASTE WEIR PLAN





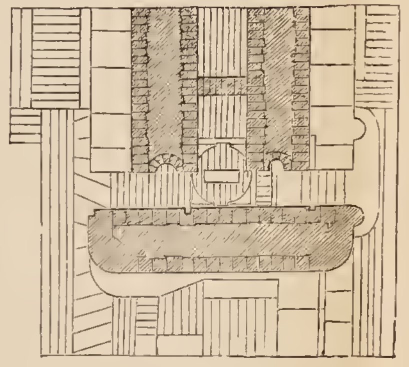
A. FIG. 2 GENERAL PLAN

C. FIG. 11 PLAN



C. FIG. 12 SECT. HORIZONTAL

HALF SECT. HORIZONTAL E.F.



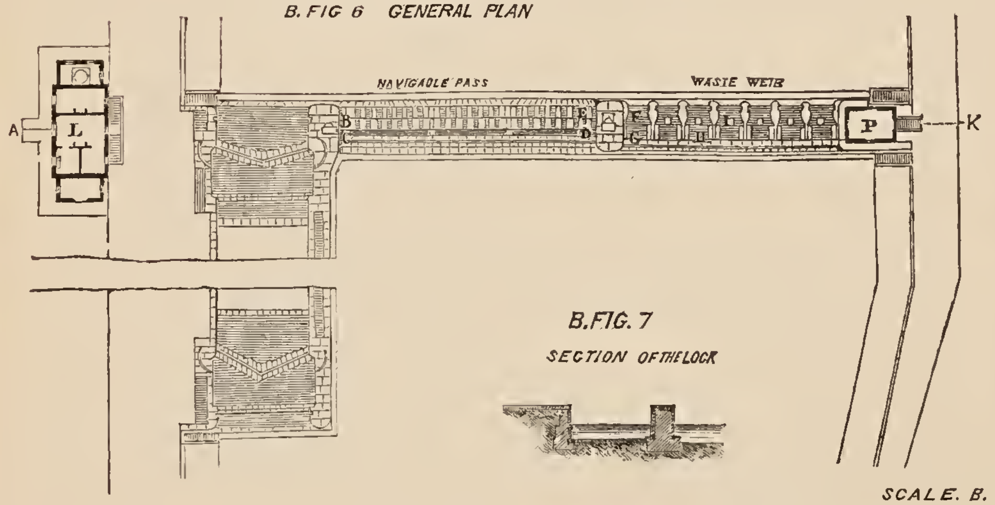
HALF SECT. HORIZONTAL G.H

DAM OF ILE BRULÉE

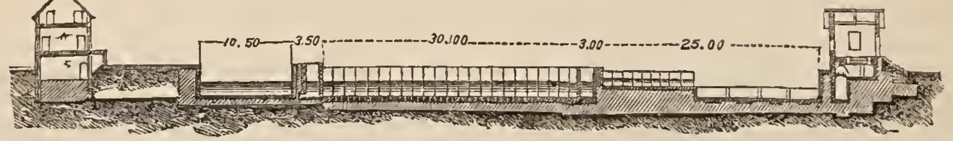
B. FIG 6 GENERAL PLAN

B. FIG. 7

SECTION OF THE LOCK

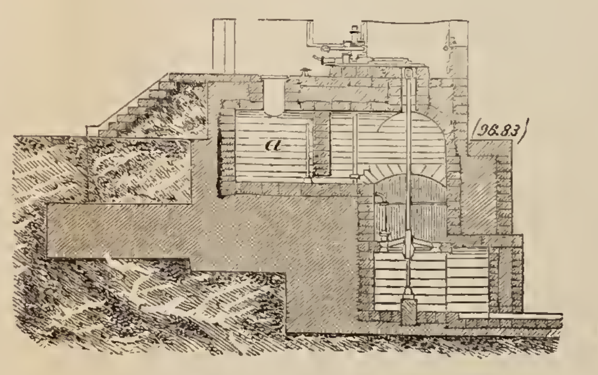


B. FIG. 8. SECTION ALONG ABCDEFGHIK.

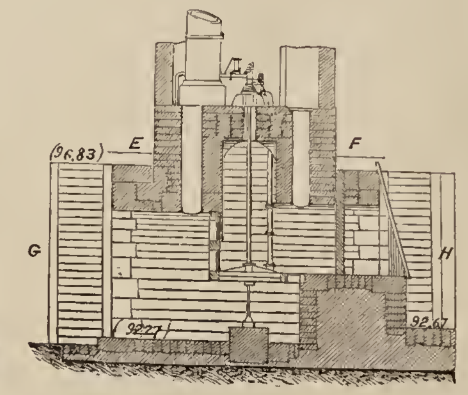


PUMP HOUSE

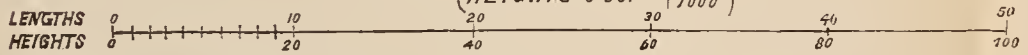
C. FIG. 9. SECTION AB



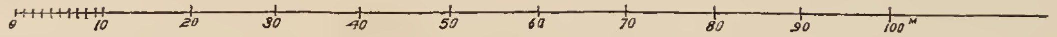
C. FIG. 10. SECTION CD



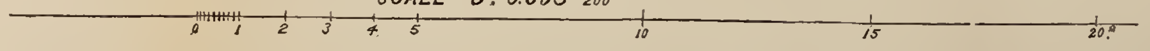
SCALES {LENGTH 0,002 ($\frac{1}{500,000}$)
{HEIGHTS 0 001 ($\frac{1}{1000}$)



SCALE. B. 0.00. $\frac{1}{1000}$

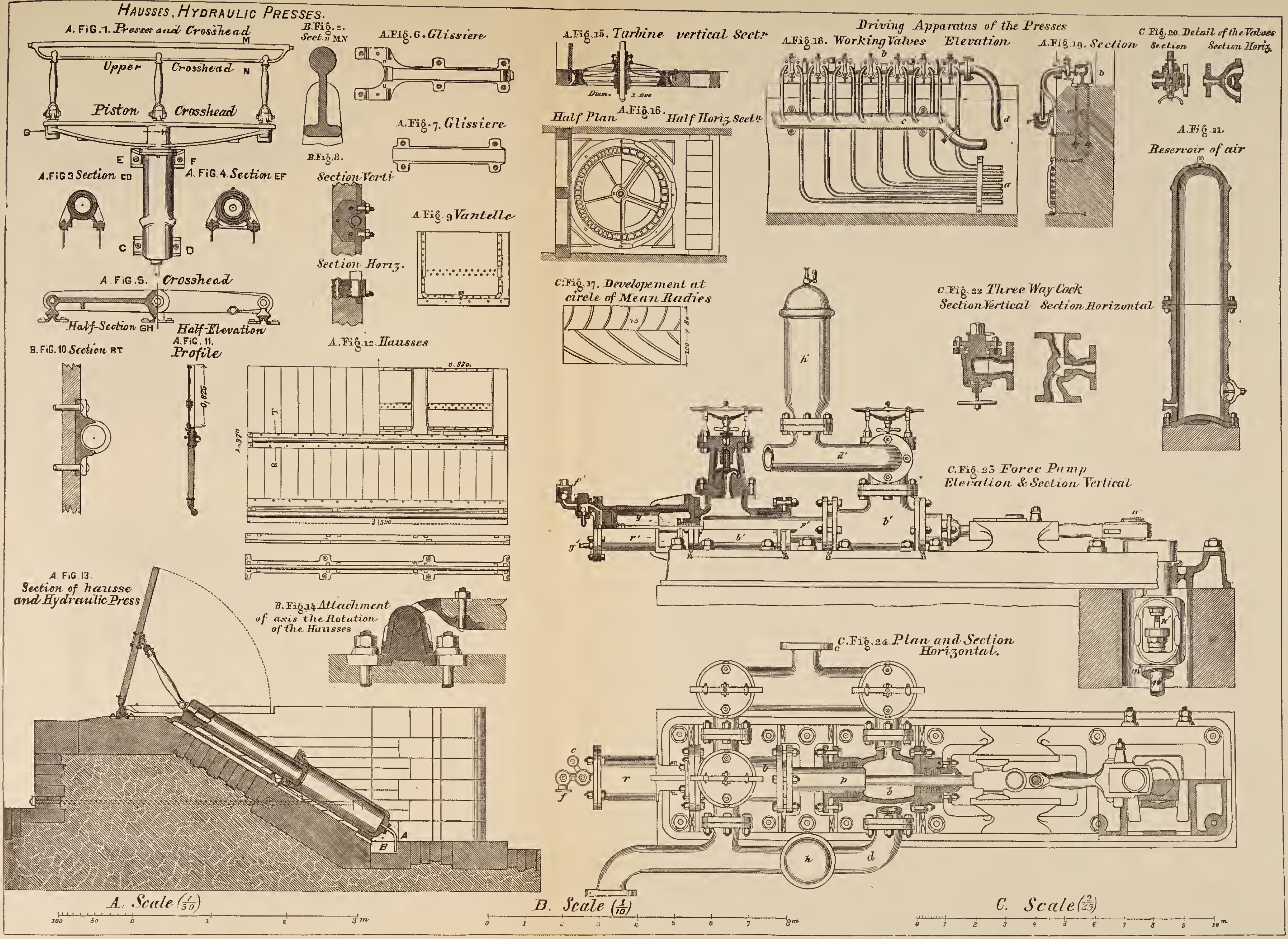


SCALE C. 0.005 $\frac{1}{200}$



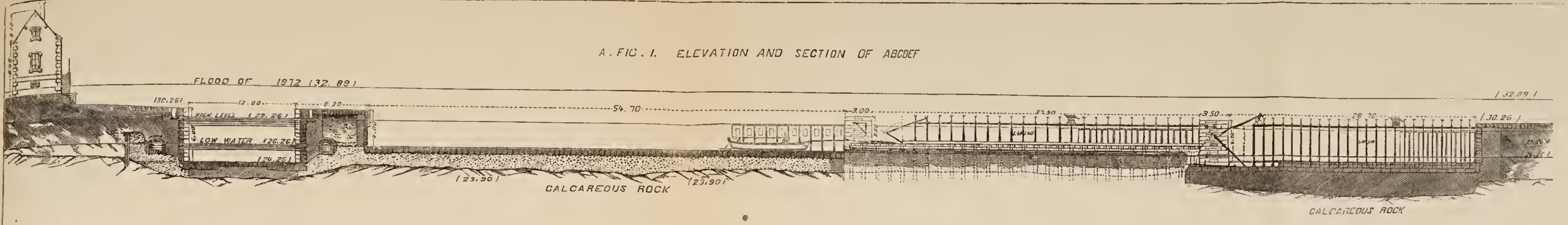
GIRARD'S NEW OVERFALL AT BRULÉE ISLAND.

PLATE XII.


HAUSSES, HYDRAULIC PRESSES.
A. FIG. 1. Presses and Crosshead
Upper Crosshead
Piston Crosshead
M
N
G
H
E
F
C
D
A. FIG. 3 Section CD
A. FIG. 4. Section EF
A. FIG. 5. Crosshead
Half-Section GH
Half-Elevation
B. Fig. 2. Sect. n MN
B. Fig. 8.
A. Fig. 6. Glissiere
A. Fig. 7. Glissiere
Section Verti.
Section Horiz.
A. Fig. 9 Vantelle
B. FIG. 10 Section RT
A. FIG. 11. Profile
0,625
A. Fig. 12. Hausses
0.880.
1.970
T
R
3.590
A. FIG. 13. Section of hausse and Hydraulic Press
A
B
B. Fig. 14 Attachment of axis the Rotation of the Hausses
A. Fig. 15. Turbine vertical Sectn
Diam. 1.200
A. Fig. 16. Half Plan Half Horiz Sectn
C. Fig. 17. Developement at circle of Mean Radies
Driving Apparatus of the Presses
A. Fig. 18. Working Valves Elevation
a
b
c
d
A. Fig. 19. Section
C. Fig. 20. Detail of the Valves Section Section Horiz.
A. Fig. 21. Reservoir of air
C. Fig. 22 Three Way Cock Section Vertical Section Horizontal
C. Fig. 23 Force Pump Elevation & Section Vertical
h'
d'
b'
p'
r'
f'
g'
a'
k'
C. Fig. 24. Plan and Section Horizontal.
c
f
r
p
b
h
d
A. Scale (1/50)
300 50 0 1 2 3m
B. Scale (1/10)
0 1 2 3 4 5 6 7 8m
C. Scale (2/25)
0 1 2 3 4 5 6 7 8 9 10m

MOVABLE BARRAGE AT PORT A L'ANGLAIS, ON THE SEINE.

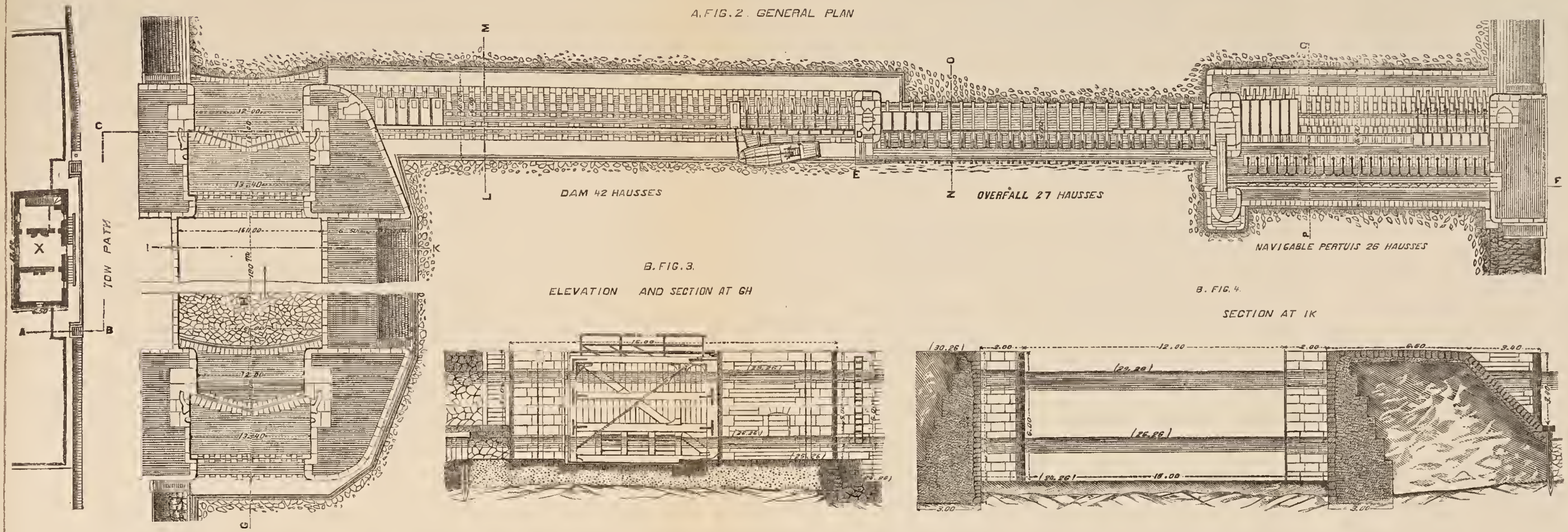
A. FIG. 1. ELEVATION AND SECTION OF ABCDEF



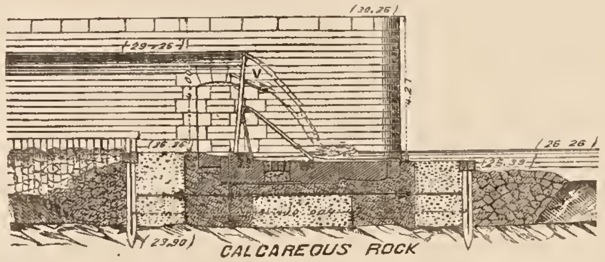
A. FIG. 2. GENERAL PLAN

B. FIG. 3. ELEVATION AND SECTION AT GH

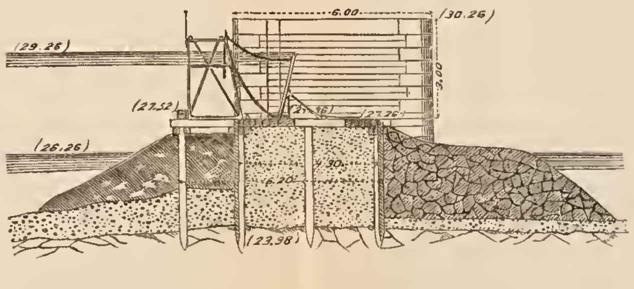
B. FIG. 4. SECTION AT IK



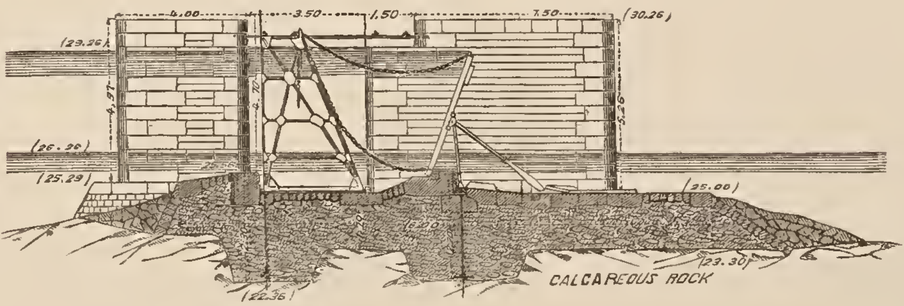
D. FIG. 5
SECTION OF DAM AT LM



B. FIG. 6.
SECTION OF OVERFALL AT NO



B. FIG. 7.
SECTION OF NAVIGABLE PERTUIS AT PQ



SCALE B 0.005

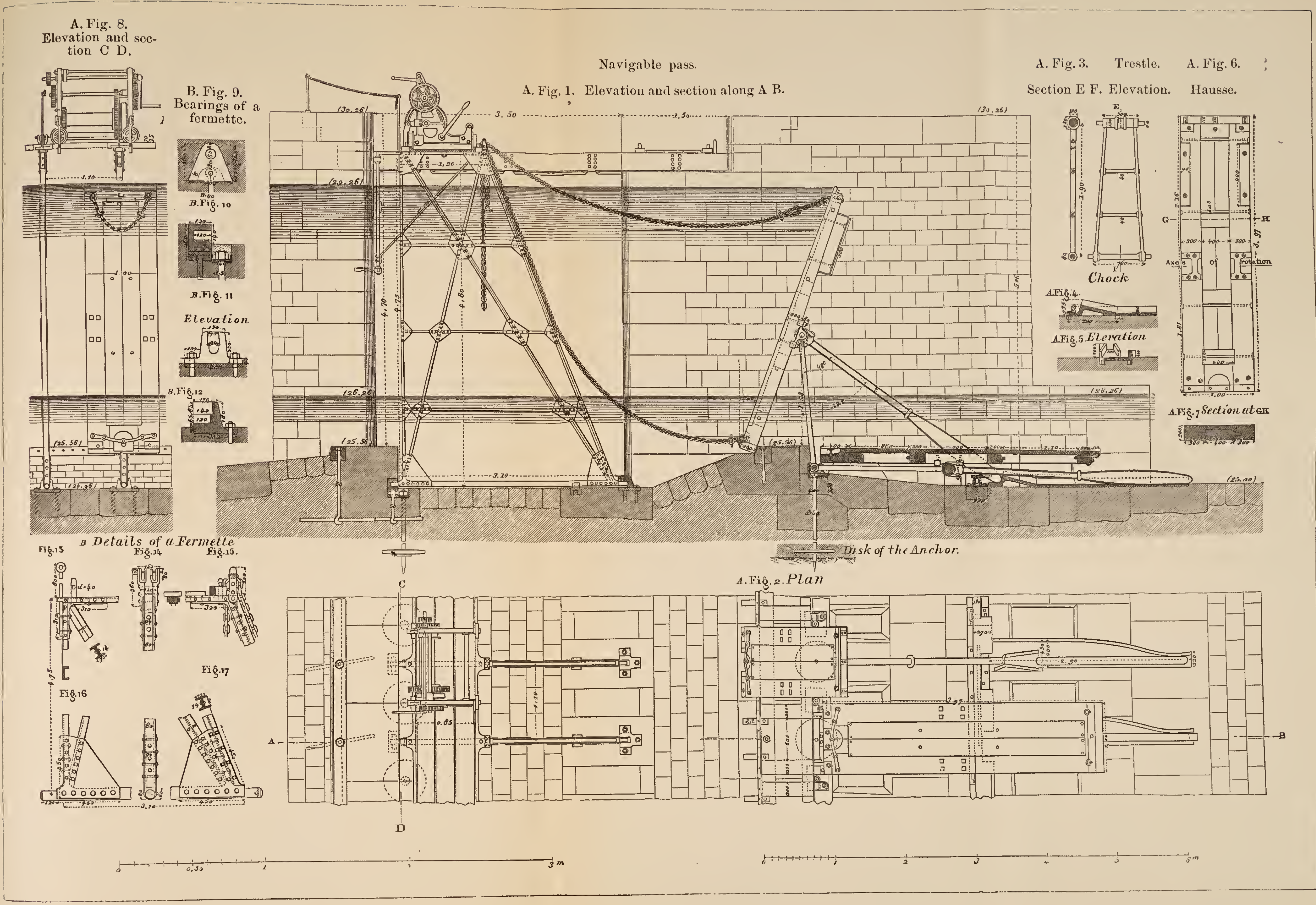
0 5 10 20m

SCALE A 0.002

0 5 10 20 30 40 50m

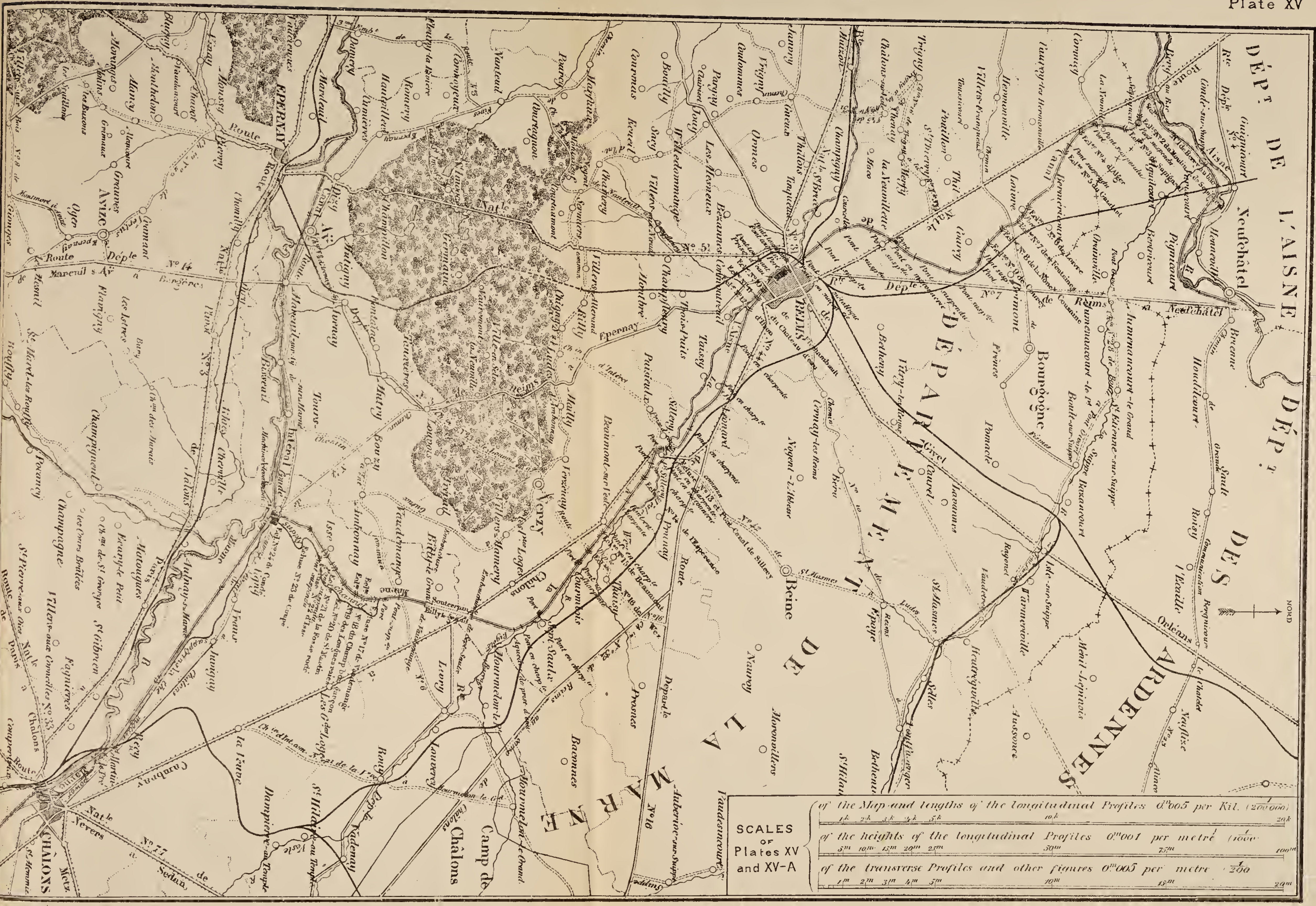
DAM AT PORT A L'ANGLAIS, ON THE SEINE.

PLATE XIV.



CANAL OF L'AISNE À LA MARNE.

Plate XV


DÉPT DE L'AISNE
DÉPARTEMENT DE LA MARNE
DÉPT DES ARDENNES
REIMS
EPERNAY
CHÂLONS
Neufchâtel
Bourgogne
Beine
Verzy
Avize
Ay
Camp de Châlons
Aisne
Canal
NORD
SCALES OF Plates XV and XV-A
of the Map and lengths of the longitudinal Profiles 0m005 per Kil. (1/200 000)
1k 2k 3k 4k 5k 10k 20k
of the heights of the longitudinal Profiles 0m001 per metre (1/1000)
5m 10m 15m 20m 25m 50m 75m 100m
of the transverse Profiles and other figures 0m005 per metre (1/200)
1m 2m 3m 4m 5m 10m 15m 20m

CANAL from the AISNE to the MARNE. Longitudinal and Transverse Profiles.

Public Works.

Plate XV.-1

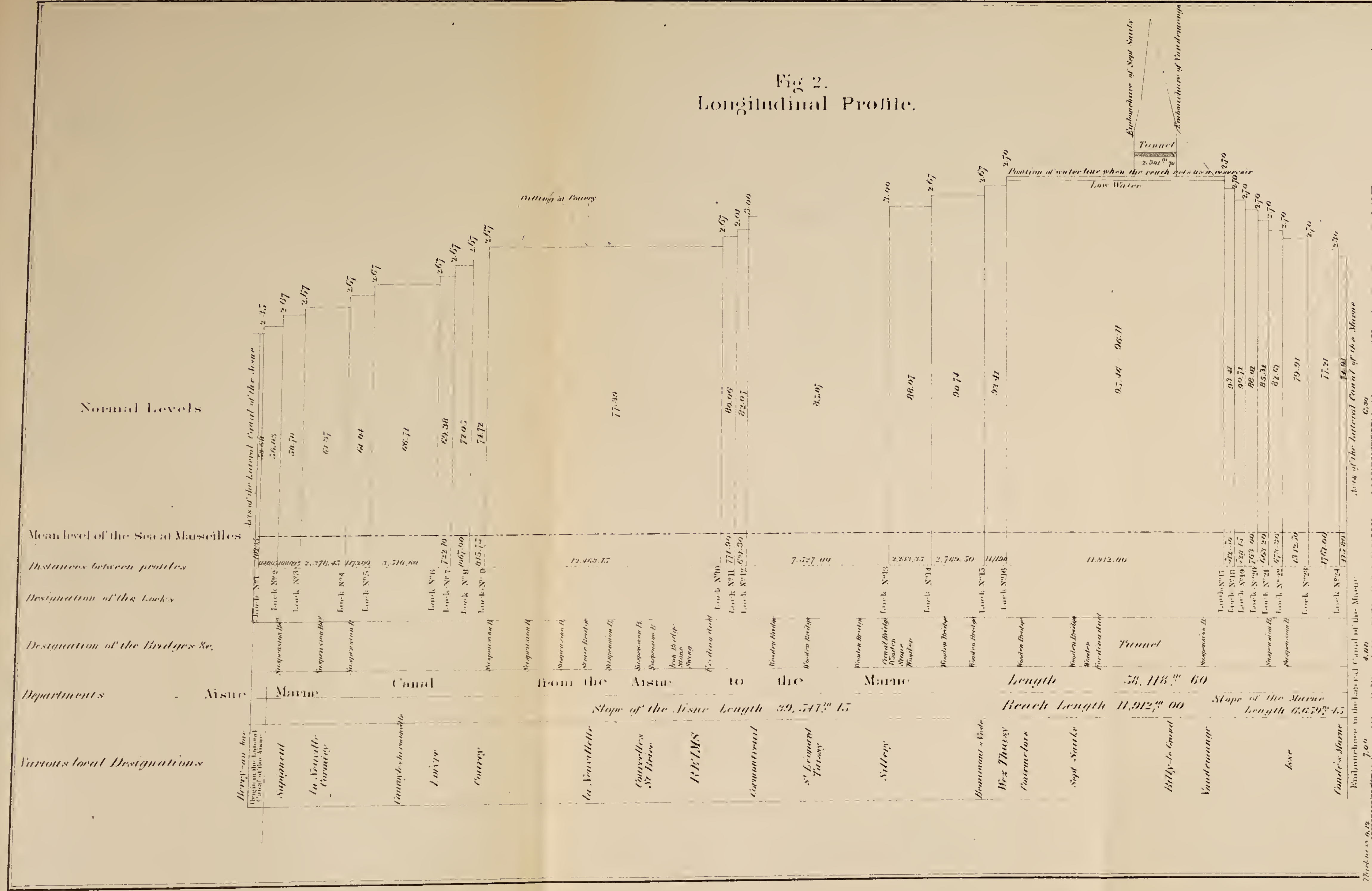


Fig. 2. Longitudinal Profile.

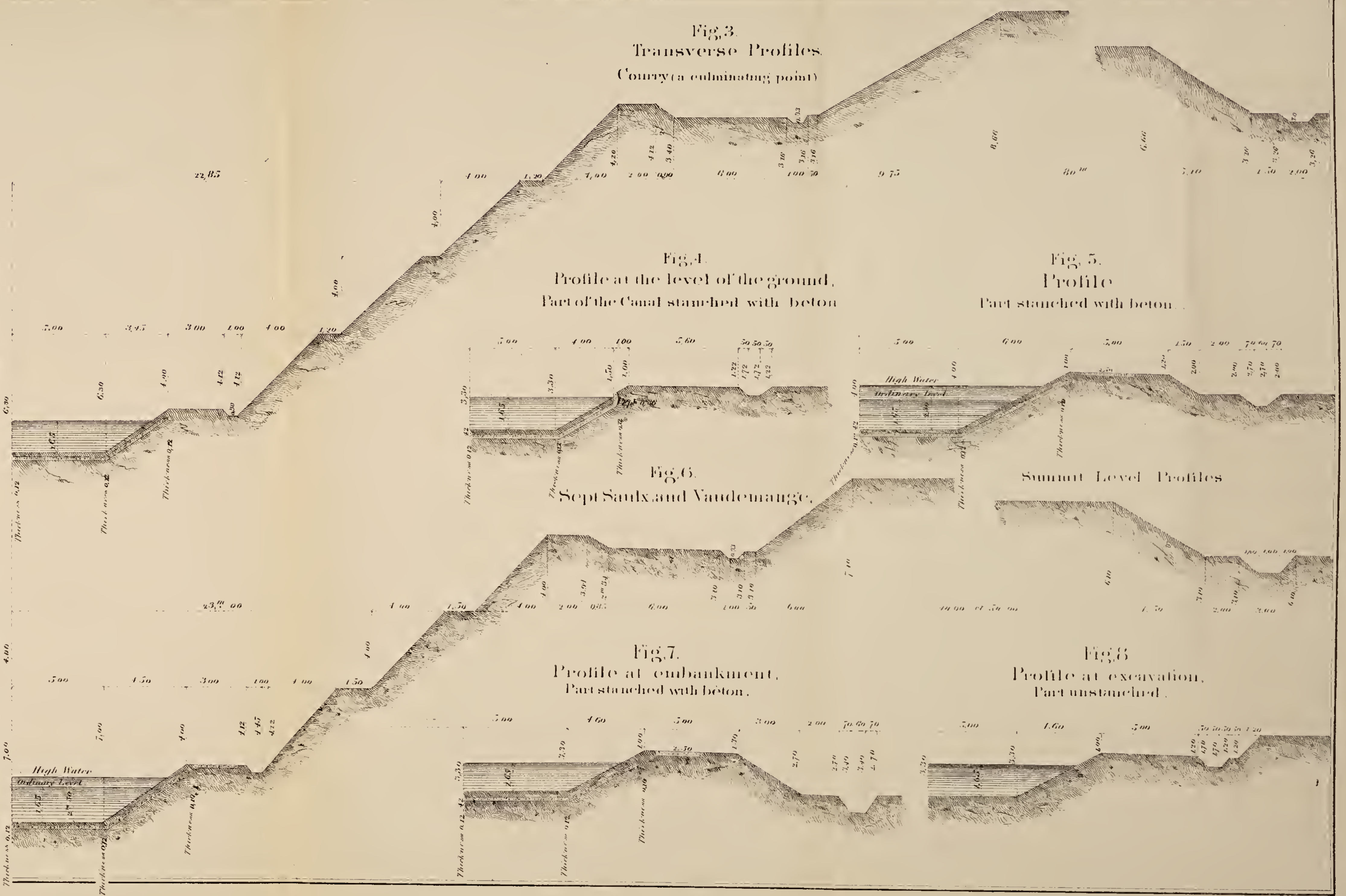


Fig. 3. Transverse Profiles. Courcy (a culminating point)

Fig. 4. Profile at the level of the ground. Part of the Canal stanched with béton

Fig. 5. Profile Part stanched with béton

Fig. 6. Sept Saulx and Vaudemange.

Summit Level Profiles

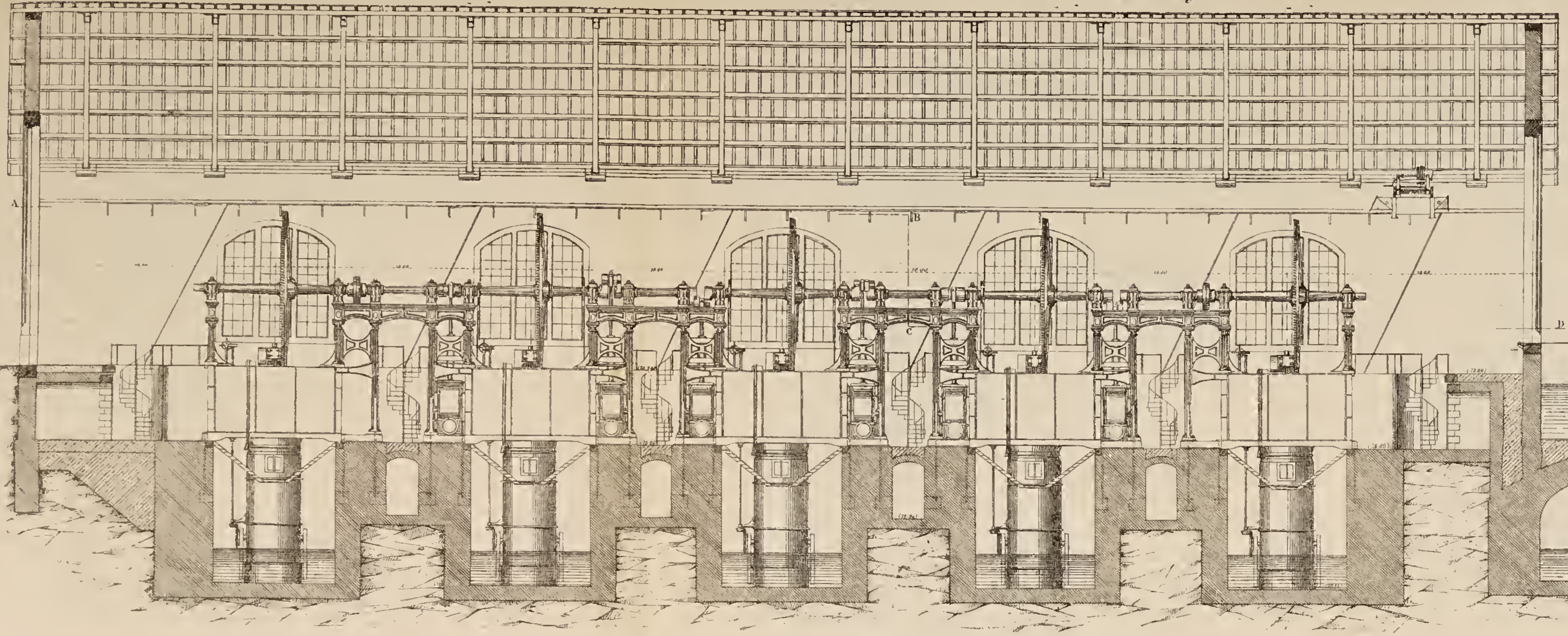
Fig. 7. Profile at embankment. Part stanched with béton.

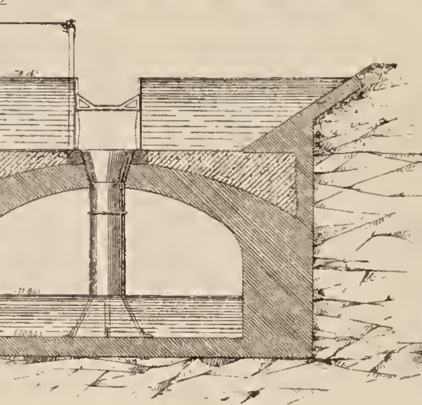
Fig. 8. Profile at excavation. Part unstanched.

HYDRAULIC PUMPING MACHINERY
of CONDÉ-sur-Marne.

Feeding the Canal of L'Aisne à la marne by Machinery.

Fig. I. *General Elevation of the Machinery View from down Stream.*

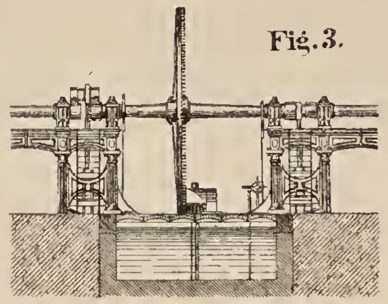




Scale 0.0042.

Turbine, up Stream View.

Fig. 3.



Section on EF.

Fig. 4.

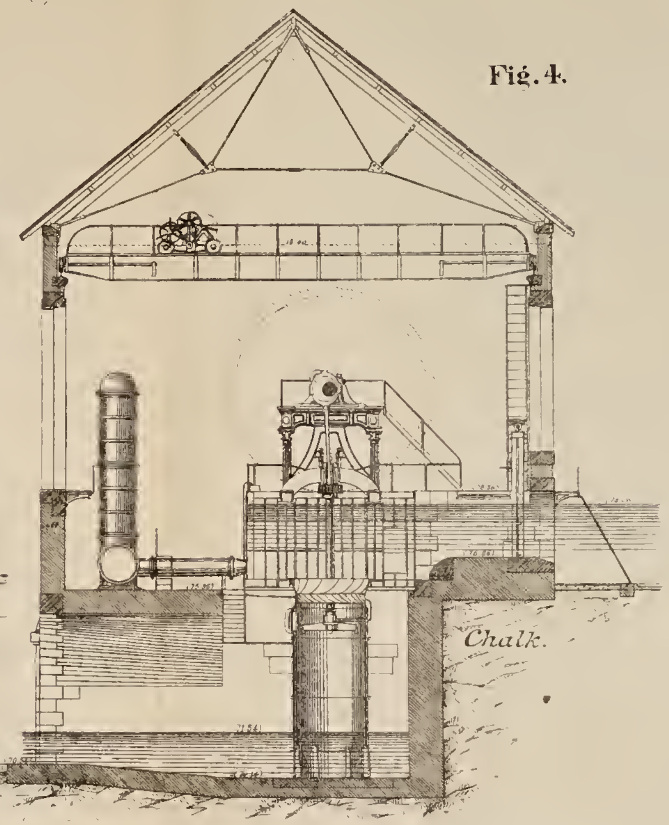
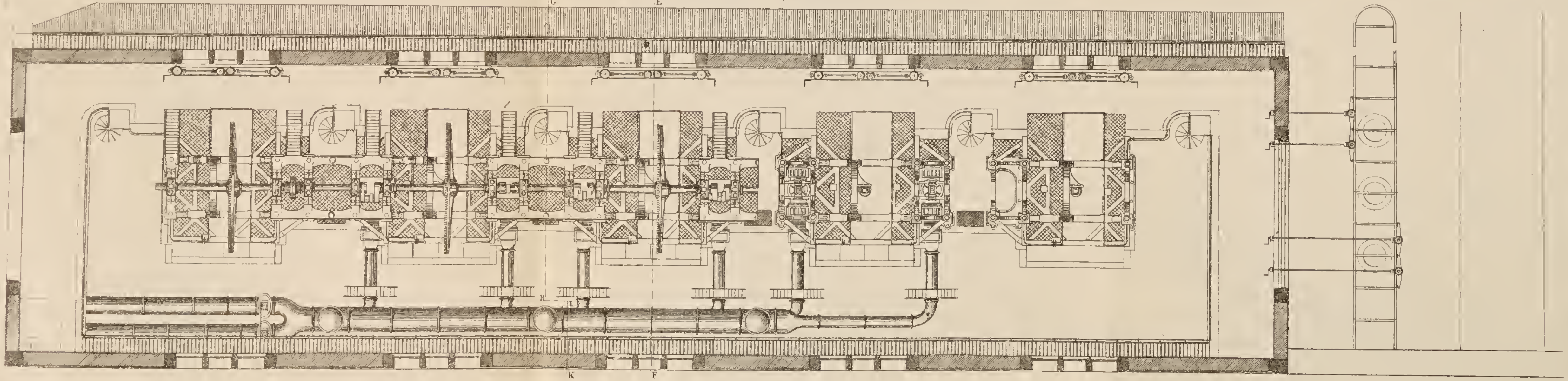
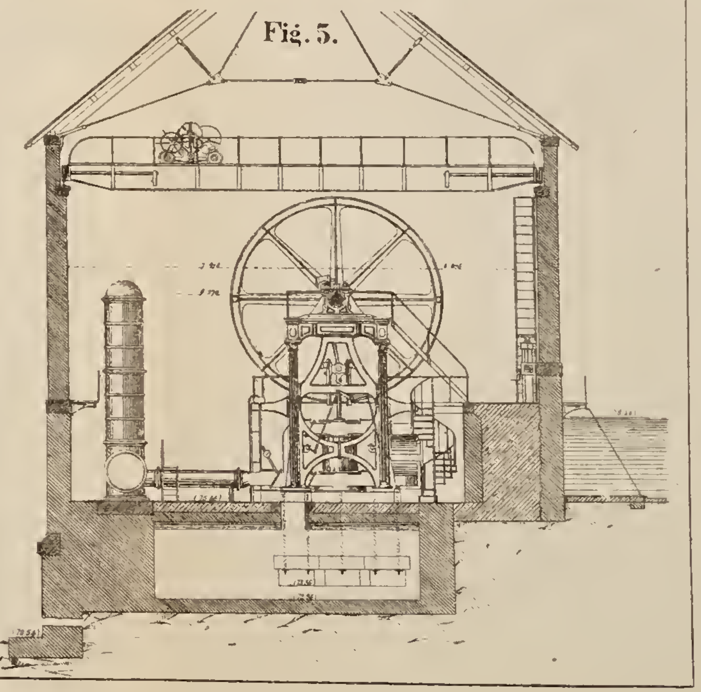


Fig. 2.
Plan on ABCD.



Section on GHIK.

Fig. 5.



American Photo-Lithographic Co. N.Y. (Osborne's Process)

Vienna Exhibition 1873.

Civil Engineering etc.

Plate XVII.

STEAM PILE DRIVERS.

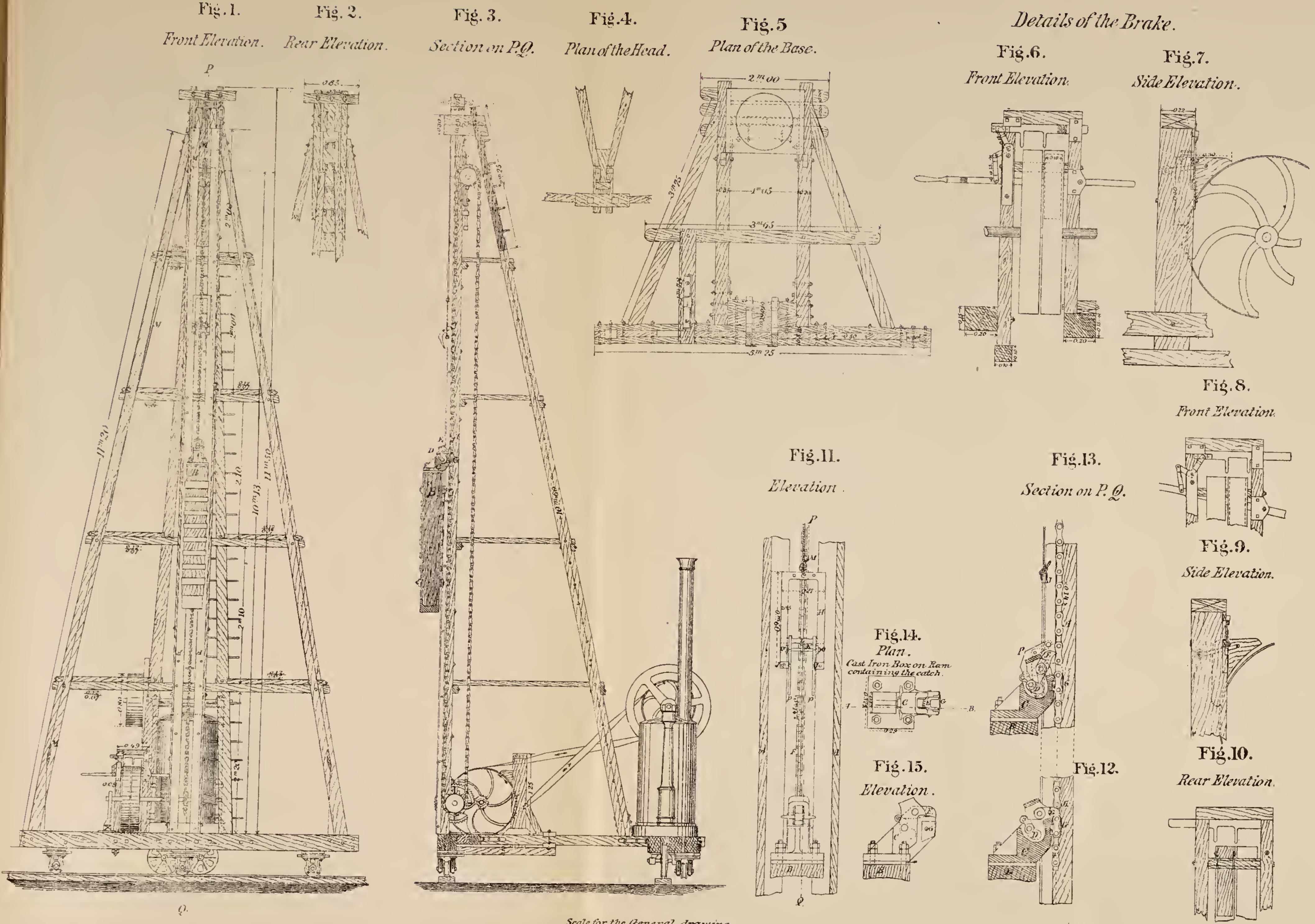


Fig. 1. Front Elevation.

Fig. 2. Rear Elevation.

Fig. 3. Section on P.Q.

Fig. 4. Plan of the Head.

Fig. 5. Plan of the Base.

Details of the Brake.

Fig. 6. Front Elevation.

Fig. 7. Side Elevation.

Fig. 8. Front Elevation.

Fig. 9. Side Elevation.

Fig. 10. Rear Elevation.

Fig. 11. Elevation.

Fig. 12.

Fig. 13. Section on P.Q.

Fig. 14. Plan. Cast Iron Box on Ram containing the catch.

Fig. 15. Elevation.

Scale for the General drawing
0 0.25 0.50 1.00 2.00 3.00 4 mètres

Scale for the details of the Brake & Catch.
0 0.10 0.20 0.30 0.40 0.50 1.00 1m50

MACHINE
FOR
MIXING MORTAR.

LEGEND.

- c. Ashes Platform.
- d. Distributor
- e. Engine Room.
- l. Bolt Platform.
- r. Ramp for Ashes
- s. Sieve or Bolt.
- t. Trass Platform.
- x.z. Platform Steps.

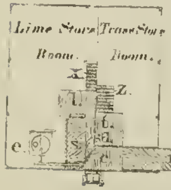


Fig. 1
Plan

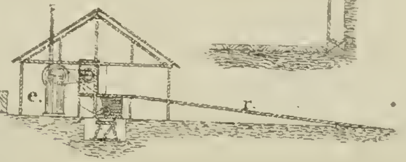


Fig. 2.
Elevation.

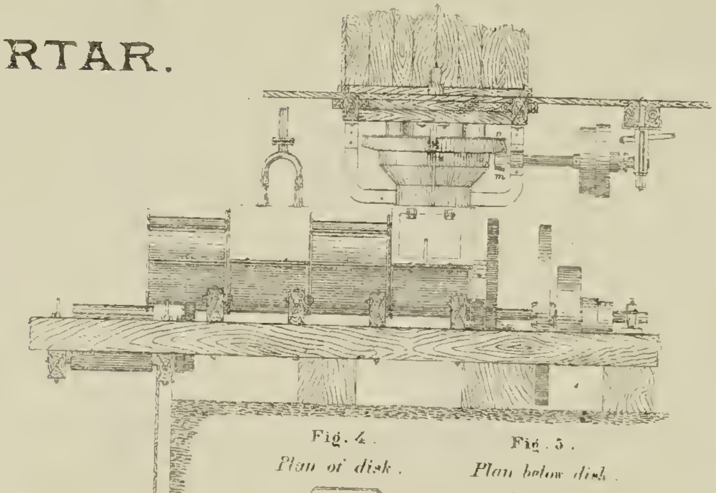


Fig. 3.
Side Elevation.

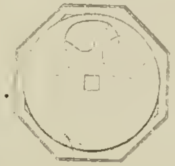


Fig. 4.
Plan of disk.

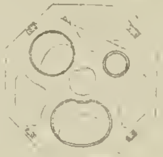


Fig. 5.
Plan below disk.

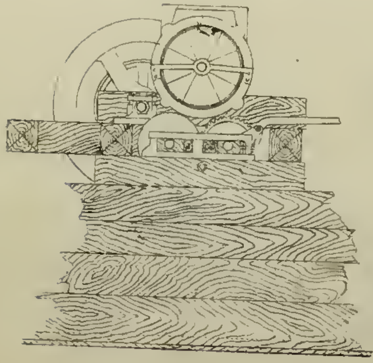


Fig. 12.
Elevation of the Machine.

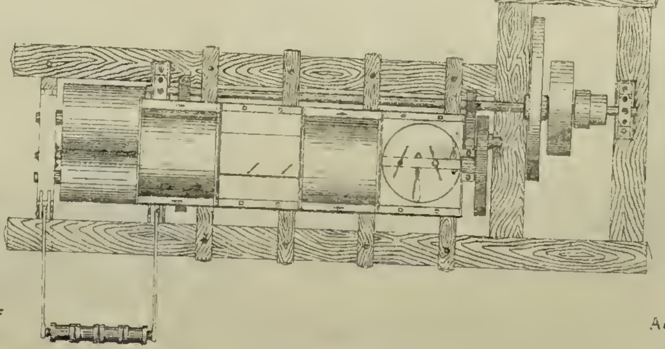


Fig. 6.
General Plan.

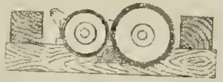


Fig. 13.
Cross section of Rolls.

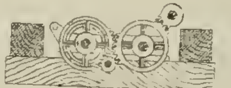


Fig. 16.
Arrangement of Gearing driving the Rolls.

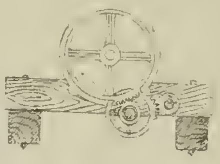
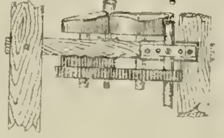
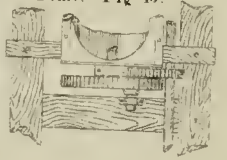


Fig. 18
Arrangement of Gearing



Plan. Fig. 17.



Plan. Fig. 19.

Fig. 14.
Elevation.

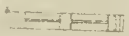


Fig. 15.
Section on a b.

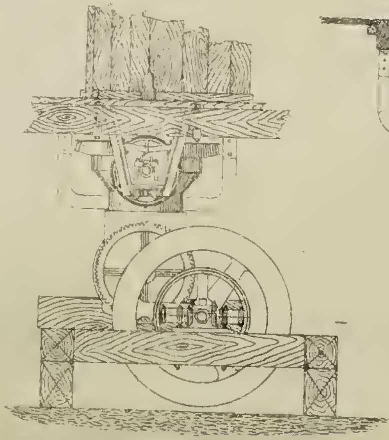


Fig. 7.
Elevation of the Machine.

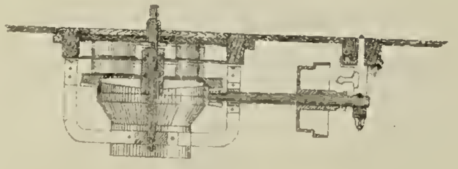


Fig. 8.
Cross section of Distributor.

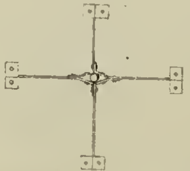


Fig. 9.
Plan of Cross.

Fig. 10.

Fig. 11.

Bevel Wheel.

American Photo-Lithographic Co N. Y. (Osborne's Process.)

Fig. 1.—General elevation.

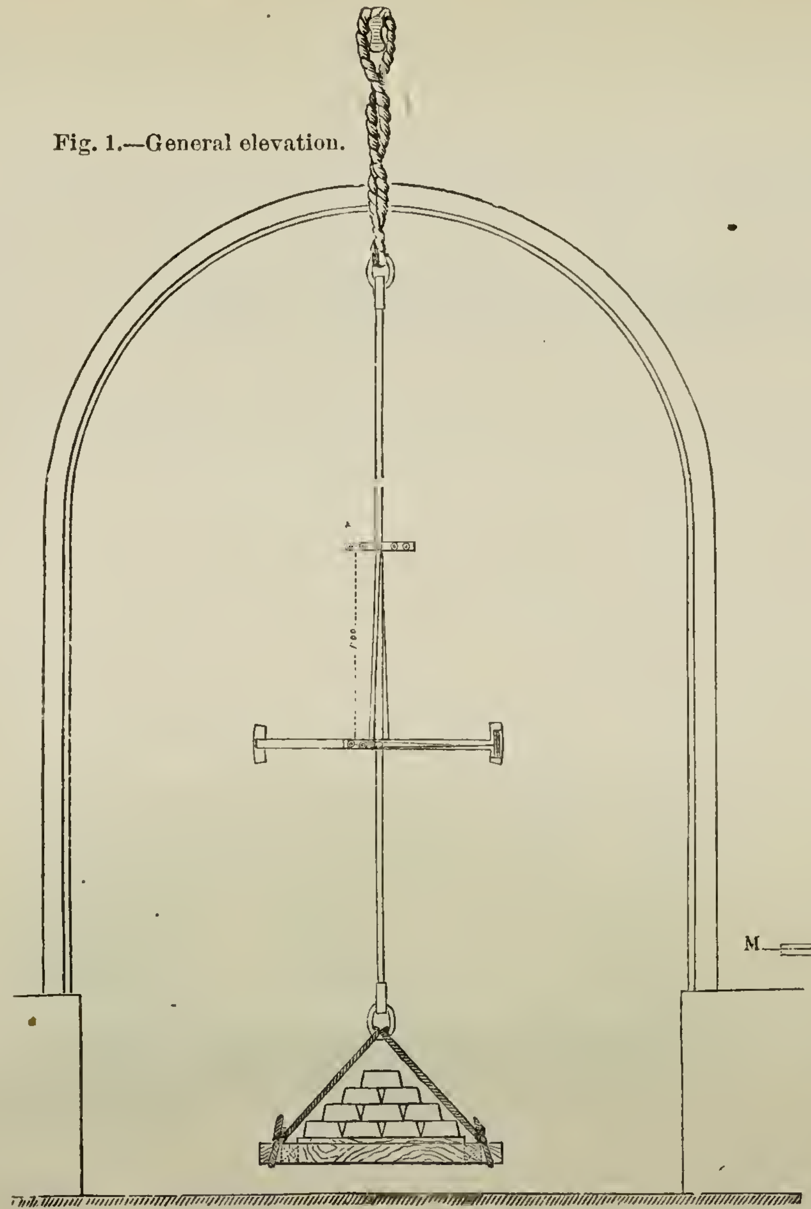


Fig. 2.

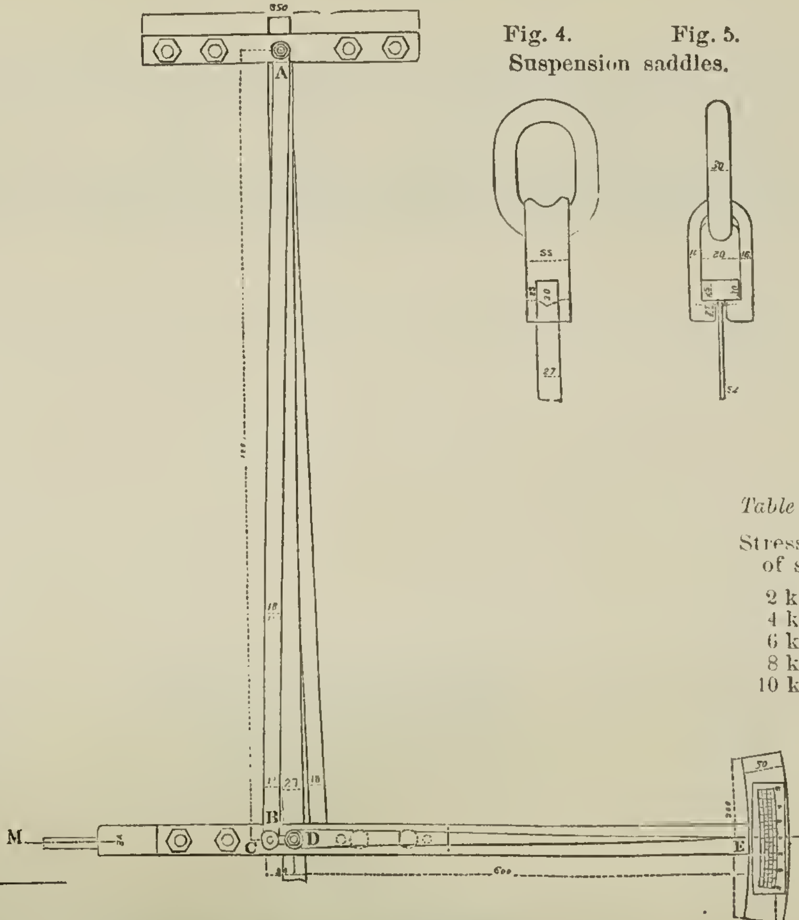


Fig. 3.—Section on M N.

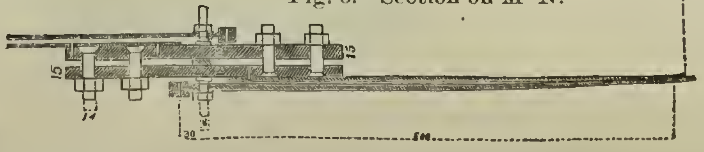


Fig. 4. Fig. 5.
Suspension saddles.

Section of
bars tested.
Fig. 6.

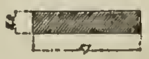


Fig. 7.

Fig. 8.

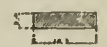


Table of elongation per meter.

Stress per mm. of section.	Elongation.
2 kilog.	0. 087 mm.
4 kilog.	0. 183 mm.
6 kilog.	0. 286 mm.
8 kilog.	0 376 mm.
10 kilog.	0. 476 mm.

Scales.
Fig. 1 = $\frac{1}{40}$
Figs. 2–8 = $\frac{1}{10}$

APPARATUS TO MEASURE ELONGATIONS OF IRON BARS IN TENSION.

TEST OF IRON GIRDER OF 11^{m}.40 SPAN.

PLATE XX.

Scale, 0^{m}.05 to 1^{m}.

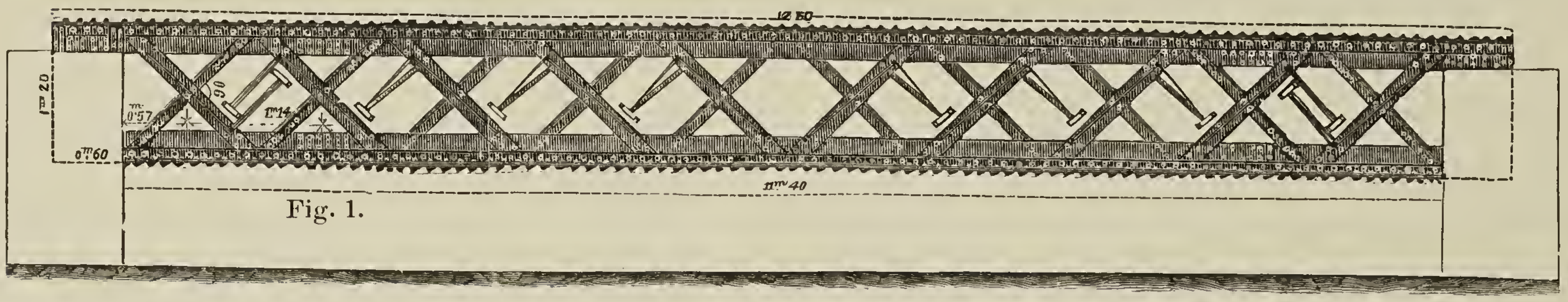


Fig. 1.

Up-stream face, apparatus attached.

Scale, 0^{m} = 10 1^{m}.

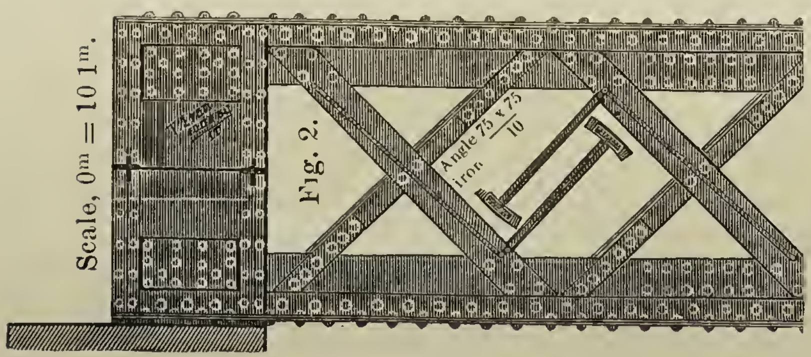


Fig. 2.

Down-stream face, without apparatus.

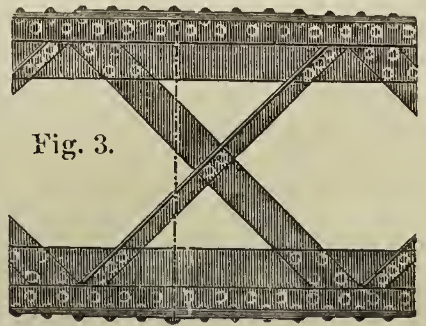
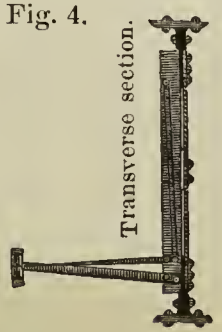


Fig. 3.

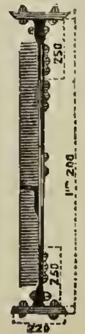
Transverse.

Fig. 4.



Transverse section.

Fig. 5.



Transverse section A B.

D.

HYDRAULIC ENGINEERING.

CHARLES DAVIS.

VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON

HYDRAULIC ENGINEERING.

BY

CHARLES DAVIS, C. E.,

MEMBER OF THE ARTISAN COMMISSION OF THE UNITED STATES

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1876.

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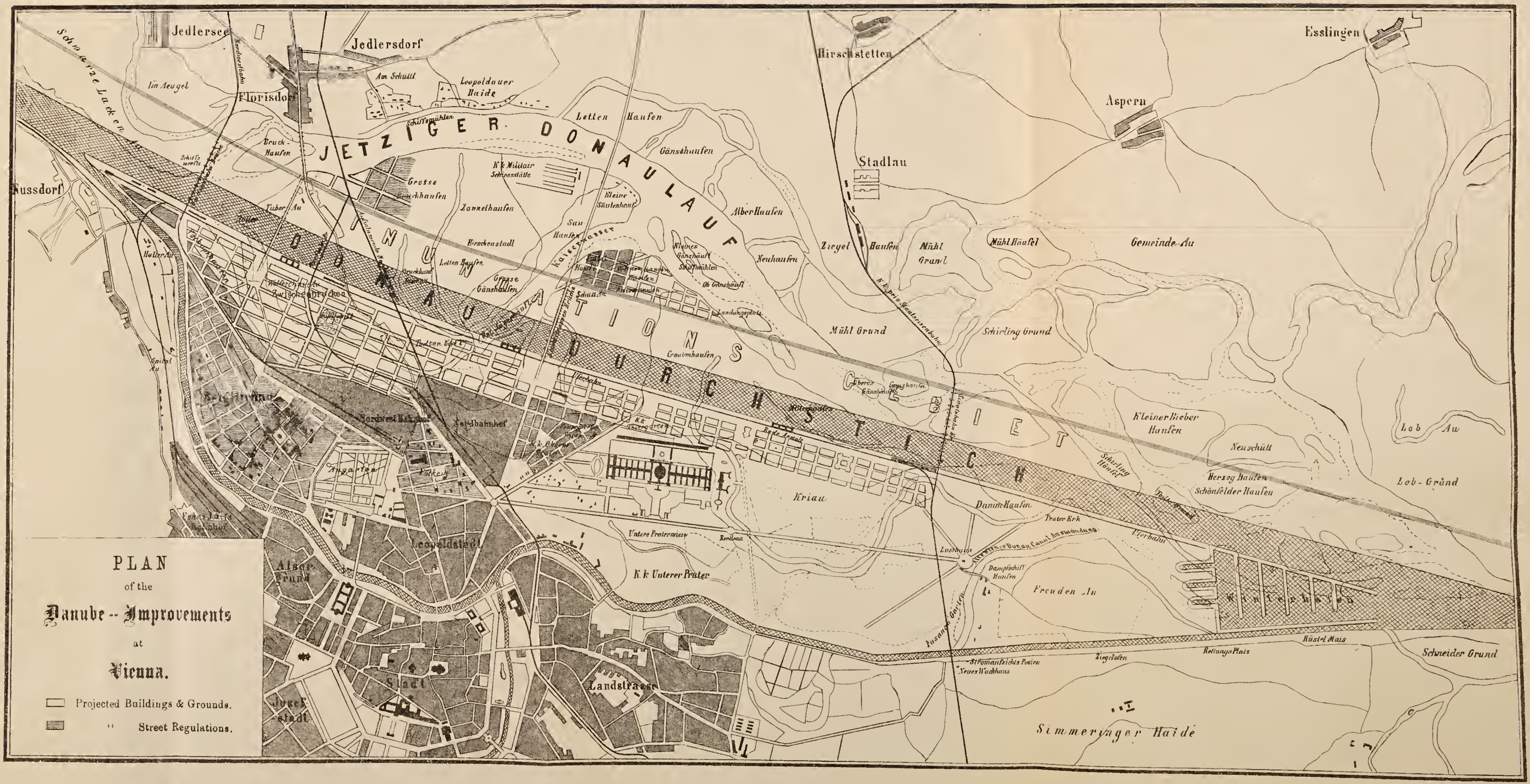
VIENNA INTERNATIONAL EXHIBITION. 1873.



PLAN
of the
Danube - Improvements
at
Vienna.

☐ Projected Buildings & Grounds.

▨ " Street Regulations.

HYDRAULIC ENGINEERING.

1. THE DANUBE REGULATION.—In hydraulic engineering the exhibits were confined to few countries. The best displays were made by Austria, France, and Italy.

In the Austrian department the most conspicuous feature of the exhibit was the collection of maps, plans, and models pertaining to the Danube regulation in the vicinity of the city, a work already far advanced toward completion, and involving an entire change of the river-bed for several miles along the city-front, with the object in view of improving navigation and of securing the city from the recurrence of disastrous floods, such as had visited it in 1862 and again in 1871.

The Danube here has a tortuous course, and from the sandy nature of the bottom-lands the river is divided up into numerous branches and the waters so dispersed as to leave insufficient depth at times for navigation. By the proposed improvement these lateral channels are to be cut off, and the water restricted to the main channel. The river is to be maintained of regular width, the shores protected by substantial banks, and provided with docks and landings, and the waste land, amounting to some 2,000 acres, is to be reclaimed.

2. DETAILS OF THE PLAN.—Plate 1 shows the plan of the diversion. The work includes not only the cutting off of the main stream from Nussdorf to Albern, but the improving and cutting off of the Danube Canal.

3. FORMS OF SECTION OF CUT-OFFS.—The cross-section of the cut-off is formed of two parts, as shown, one for ordinary stages, and the other for carrying off the floods. The first has a width of 929 feet, this being considered sufficient to secure the required depth of water for constant navigation. The high-water bed is bordered on the current portion by inundation-dams on both sides, and has a width (including the low-water bed) between the banks of 2,478 feet, or nearly one-half mile. In the whole distance, over six miles, between Nussdorf and Albern, there are two cut-offs. One, comprising about one-half the distance, (between Roller and Stadtlauer bridge,) has the whole stated width excavated to the full established depth of 10.4 feet below datum. The other, a little less than two miles long, extending from Steinspornhaufen toward Albern, is only excavated to the width of 371.6 feet, and to the depth of 8.15 feet below datum. All the material excavated is needed to fill up the old arms and to raise low portions for building. In front of the city, the high-water bed of a width of 929 feet is shifted to the

left side of the stream, and, instead of an inundation-dam, the earth is deposited as shown in the cross-section.

4. EMBANKMENTS.—The bank-line is built up to the maximum summer high-water line, 12.39 feet above datum; from this line the embankment ascends gradually for a distance of 620 feet to the line of the first parallel street of the projected Danube town, where it attains an elevation of from 2 to 4 feet above the flood-level.

The section of banks is shown in the figure. The slopes are pitched with stone. On the right bank, for a portion of the distance, a vertical quay-wall is substituted.

The height of the crown of the inundation-dam near the mouth of the canal on both sides of the stream-bed is 18.5 feet above datum, and for the upper-slope portion 20.5 feet. The left is raised 6.1 feet at the back edge, and 8.1 feet above datum at the foot of the dam. The right, below Vienna, is raised at the edge of the bank to 6.1 feet, and at the foot of the dam to 10.4 feet above datum.

5. BASINS.—The old works at Nussdorf are leveled off to the established profiles. The point between the mouth of the Danube Canal and the new Danube is made into a winter harbor; this contains an area of 160 acres. The old Danube bed from Nussdorf to Stadtlauer bridge will also be appropriated for the same purpose, connecting with the new bed at two points; the area of this basin is 290 acres. The improvement when completed will give about twenty-seven miles of landings.

6. THE DONAU CANAL.—In connection with the regulation the Danube Canal is to be improved. This is not an artificial channel, but a branch of the Danube, which, by continued improvements and regulation, has been brought to a good navigable condition. The width varies from 150 to 159 feet; the slopes are mostly paved, and protected by piles. The banks are from 10 to 12 feet high, except at the prater, where the left bank falls to 8.8 feet. In connection with the new work the canal is to be excavated 7.1 feet throughout its length, and the banks strengthened, so that no fears need be entertained of overflows from this quarter in future, except in cases in which the canal becomes gorged with ice.

7. FLOODS AND ICE-GORGES.—The old water-course through the city has been a constant source of danger, by reason of ice-gorges and floods. Where the water enters the canal, at Nussdorf, the canal-opening is in an almost direct line with the course of the natural stream. The Danube here deflects abruptly to the left, and the current is very strong. As a consequence, in winter, the ice is driven directly down this canal, and, its fall being less than the main stream, and its outlet at an unfavorable angle for rapid discharge, gorges are formed, and the low sections of the city inundated.

To obviate this, the Danube regulation commission have adopted an expedient of damming off the ice by a floating caisson at the head of the canal. (Fig. 2.) A model of this novel contrivance is exhibited in

DANUBE IMPROVEMENT. (Page 6.)

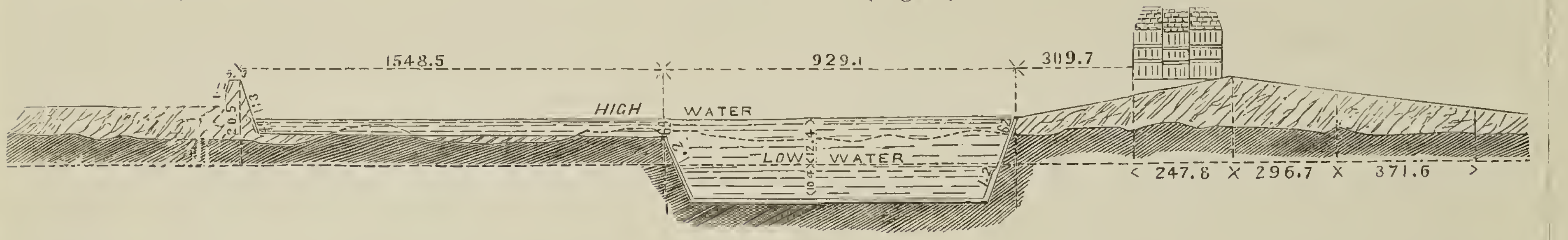


Fig. 1.—Embankment.

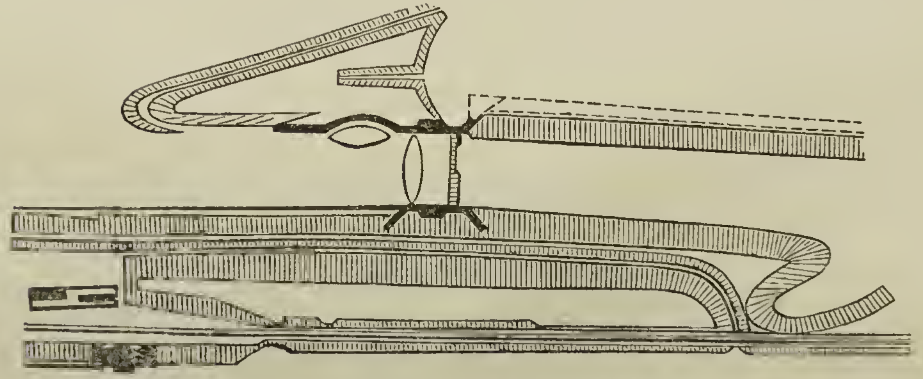


Fig. 2.—Position of floating caisson.

the Belgian section by Mr. John Cockerill, and the caisson itself is anchored in the Danube near Nussdorf, preparatory to its being placed in position at the head of the canal. The throat of the canal is contracted somewhat, and the sides built up with massive granite walls to receive this gate.

8. THE CAISSON.—The caisson is a monitor-like structure, with a swelled section in the middle, and pointed at the ends, and with vertical sides. Its length is 159.7 feet; width in middle, 31.2 feet, and height 18.5 feet; and is divided into five compartments by four vertical divisions. It has also a horizontal division midway of its height. The skeleton is made of heavy wrought-iron girders, and the sheeting of $\frac{5}{8}$ boiler-iron, with Bessemer steel plate bottom, and weighs 360 tons. The compartments are arranged to communicate with each other by means of valves, and the caisson is raised or lowered by admitting or emptying the water, as the case may require. The deck of this vessel is furnished with steam-pumps for pumping out the water, and also with capstans for the mooring-chains. The caisson-seat is protected by a stone pavement on a bed of béton to prevent underwash. The gate is designed to vent sufficient water to float the shipping in the canal, and at the same time to hold back the ice. To put the gate in place when the ice begins to run, the chains are attached to the moorings on the banks, and the caisson swings around out of the recess on the left bank against its bearings at right angles to the stream. The bearing on the right bank is not against the abutment direct, but against two movable iron shutters; one projecting slightly beyond the face of wall, and the other acting as a brace to hold this to place, and to carry the strain back to the wall. When the gate is to be opened these doors are drawn back into a chamber, and the caisson swings down stream and opens the passage.

9. THE LOWER DANUBE.—The Danube between Vienna and Pesth has pretty much the same character of bed as in the vicinity of Vienna. In many places, especially below Presburg, where the country is flat and sandy and the river-banks low, great difficulty is experienced in keeping the stream confined to one channel, and the navigation in a safe condition. The disposition of the stream is to separate itself into several branches, and thus to create shoals. At such points the plan of protection usually adopted is to throw out fascine spurs at right angles to the banks or shores at suitable intervals in the shoal places, and bringing the ends of these spurs to line to prevent any injurious diversion of the current. These spurs are formed by gathering fagots of swamp-brush in bundles as large as a man's body and placing them in alternate layers (longitudinal and crosswise) in the form of a barricade or dam. The bundles are firmly pinned to the ground, and to one another; the sand washing into them gives solidity and weight to the mass, and in time the sprouts from these fagots form a thick growth on the top of the dikes. This gives a cheap and effectual mode of protection. At several different points the writer noticed works of this kind in progress.

This method of protection has been in vogue on this river for many years. The current of the Danube is very swift, running, in ordinary stages, at the rate of from six to eight miles per hour.

10. IMPROVEMENTS NEAR BUDA-PESTH.—In the vicinity of Pesth colonies of floating flour-mills dot the surface of the river, the wheels of which are driven by the current of the stream. At Buda-Pesth permanent quays of granite are being erected on the new regulated lines; portions of these are built with landing stairs to accommodate the passenger and market traffic. Portions are built with a vertical face for the use of the heavy shipping.

In the best quarter of the city, immediately behind the quay, parallel with it, and some 18 feet above it, a handsome boulevard is laid, commanding the finest view of the two cities, and the river. Fronting on this boulevard are blocks of buildings, which, for size and finish, compare favorably with the finest in Paris or Vienna. These improvements are built in the style of the river improvements of Paris and London, and with them are in marked contrast with the practice of American cities in improving river-side property and providing wharves and landings.

11. PNEUMATIC PIER-SINKING.—Two interesting exhibits were made, showing methods of founding bridge-piers by the pneumatic process; one from the firm of Kleine Brothers, Schmoll & Gartner, of Vienna; the other (in the German section) from the Berlin and Hamburg Railroad Company. They were very elaborately worked out, showing shafts, air-chambers, and locks, and the mode of operating. There were no new features observable, however, beyond what has already been developed in the application of this process, to the founding of piers in this country, as at the Saint Louis and East River bridges.

12. TIMBER TRANSPORTATION.—The joint stock association for forest industry at Waidhofen, on the Ybbs, had on exhibition a fine collection of charts, models, and photographs, illustrative of their works and possession on the tributaries of the Danube. The models were to show the system of dams, chutes, and appliances for the transport of timber A visit to this section and to Buda-Pesth, on the Lower Danube, was of material assistance in obtaining a practical notion of the character and interest of this work on the Danube. This company have control of something like one hundred and twenty square miles of forest, natural and cultivated, on the Ybbs and Earlaf. They have spent large sums in regulating these streams for the purpose of getting their products to market.

The Earlaf has but recently been improved, the work comprising blasting rock, making cut-offs, and bank protections. The cost was about $1,700 per mile.

The Ybbs is about eighty miles long, and falls 3,526 feet. The Earlaf is shorter and falls 2,000 feet. Near the sources the fall is very heavy, about 150 feet to the mile. In this region the mountains are high and precipitous, and stand in isolated peaks with deep ravines running between.

Waidhofen has a beautiful situation between high mountains.

13. DAMS.—The movement of the floating timber is regulated by means of dams which are generally built of wood, with inclined chutes at one side, so placed as to bring the upper sole two feet lower than the crest of the dam. The opening is closed by a trap, or gate, which is removed on the approach of a raft, and replaced after its passage, to avoid a useless waste of water.

The natural supply of water will not serve for navigation, except in the early spring while the snow is melting. At other times, the use of reservoir-dams, controlled by sluice-gates, is resorted to, and the timber is floated by artificial swells.

A raft, in its passage on the Ybbs, encounters no less than twenty-six wiers, including those used for industrial establishments, varying in height from 7 to 16 feet. These rafts are made up so as to be flexible and to accommodate themselves to the sharp bends and irregularities of the stream.

In addition to the ordinary dams there are several gathering or rake dams. These are appliances to collect the loose timber and cord-wood, which, in the first stages of the floating season, before rafting begins, is set adrift. These dams are provided with sluices and side basins.

The floating timber is kept in the water by men stationed at points along the shores. Their duties are also to act as guards and to prevent gorges. In case gorges do occur the storage reservoirs are brought into play to float the timber off.

14. THE WATER-SUPPLY OF THE EXHIBITION.—The water-works erected for the use of the exhibition made an interesting feature in this branch of engineering. The supply is drawn from wells sunk to the gravel bed of the Danube, some 20 feet below the surface. The high-service is supplied from a boiler-plate tank, 24 feet in diameter and 18 feet high, resting on a skeleton iron structure 110 feet high, located near the west entrance. This water-tower is octagonal in form and is composed of nine cast-iron flanged columns of 16 inches diameter, connected together laterally at intervals of about 16 feet by heavy channel girders, and with diagonal bracing in the panel spaces. The tower rests on a brick base about 15 feet high, and were provided with a winding stairway and gallery around the tank, affording a good view of the grounds. The water is forced through the central column and is discharged by two of the side-columns. The structure presented a fine appearance making one of the attractive ornaments of the grounds and had the merit of being decidedly simple in construction. An engine capable of lifting 16,000 cubic feet per hour supplied the tank.

In another part of the grounds an independent system of pumps is employed for pumping direct from a well into distributing-mains, using the reservoir only as a regulator, thus making an arrangement something like the Holly plan of water distribution.

The Machinery-Hall is also supplied in part from drive or tube wells in connection with pumps, using a small reservoir for storage.

Professor Ritter von Grimburg designed the tower and works.

15. WATER-SUPPLY OF VIENNA.—The new water-works at Vienna are especially interesting on account of their magnitude and as presenting some features not common with us. The present supply is very defective, and is partly derived from wells and springs, and partly from the Danube near the city. By the new scheme, water is to be furnished from springs in the Semmering, fifty-eight miles distant, by a gravitating supply, involving about four and a half miles of tunnels and one and three-fourths miles of viaducts, and the balance of the distance by a conduit following approximately the surface of the country.

16. VIADUCTS.—At Moedling, a short distance from Vienna, the conduit emerges from a long tunnel on the south side of the valley, passes over the valley by a viaduct of seven arches, 85 feet high and of 54 feet span, and then again by another tunnel to the Lissing Valley, which is crossed by an aqueduct, 50 feet high and 2,000 feet in length, divided into forty-four openings of various spans, seven arches of 30 feet, thirty-five arches of 42 feet, and one of 60 feet.

In approaching Vienna, these works make an imposing feature in the landscape, and are scarcely less striking than the old aqueducts of the Romans across the Campagna, as they appear to the view off the road from Rome to Naples. The viaducts are built of brick with stone trimmings. The water-way for conduit is generally of rectangular section, 4 by 6 feet, with arched top. Where the crown of the conduit follows the surface of the ground, it is covered with earth to the depth of six feet to prevent injury from heat or frost. The water-way of the conduit is made smooth by a thick coating of Portland cement.

17. DISTRIBUTING-RESERVOIR.—The conduit delivers the water into a distributing-reservoir 280 feet above the Danube, located at Rose Hill, in the suburbs of Vienna. This reservoir is divided into two compartments, and is so arranged that either division can be cut off at will. Two other larger reservoirs are built in different quarters of the city, each supplying a certain district. These reservoirs can be worked together or independently. By this arrangement, in case of accident to any part, the disaster would only be local. A third reservoir is built for the lower part of the city, at an elevation of 162 feet above the Danube.

The reservoirs are all vaulted structures, built of brick, covered with earth, and faced inside with cement. They are lighted and ventilated with circular openings in the crowns of the arches. This mode of construction is adopted to protect the water against atmospheric influences.

From Rose Hill reservoir a brick overflow conduit leads to the Lessingbach, to carry off the surplus water. Both the large reservoirs are about 250 feet above the Danube. The capacity of one is about 240,000 cubic feet, and of the other 140,000 cubic feet. The depth of water carried is 12 feet. These reservoirs are all provided with self-acting sluices and the proper regulating-apparatus. The portal and gate-house of the Rose Hill reservoir is a very imposing structure; the grounds are neatly trimmed and planted. The estimated cost of this work is $8,000,000. They were commenced some four years ago, and are now about completed. This improvement, together with improved drainage, will no doubt make Vienna a much healthier city.

By some peculiar legislation, a large proportion of the houses in certain quarters of the city are exempt from water-tax for some years to come.

The water-works were designed by M. Junker, chief engineer of Vienna.

18. SEWERAGE OF VIENNA.—The city has very defective sewerage, as is generally the case with the old cities of the continent. This, in connection with the use of impure water, (well and river water,) and the peculiar situation of the city, bordering on a great plain, with the Danube divided into many branches, and continually shifting its bed, leaving at times great sloughs and stagnant pools to contaminate the air, makes it very susceptible to malarious influences. This defect cannot be corrected until the new water-supply is brought into general use, the sewerage-improvement completed, so as to carry away effectually and promptly the daily waste and filth of the city, and the waters of the Danube confined to a single channel by the projected regulating improvement. Vienna, notwithstanding her great works, is at present without a connected scheme of sewerage. The Danube Canal carries the discharge of most of the sewers. The three creeks, the Weinfluss and two smaller ones, running through the city, have to some extent been converted into great trunk sewers. The last two have been arched over, while the Weinfluss, traversing the finest quarter, still remains open, and is kept in a tolerably good condition by the enforcement of an ordinance prohibiting the deposition of filth therein. It is scarcely less odorous, however, than the sluggish Tiber Creek of Washington. To further guard the Weinfluss from contamination, an intercepting-sewer is laid along each side of the stream, with overflow-openings at suitable intervals to discharge storm-waters into the creek. These intercepting-sewers also discharge into the Danube Canal, and are designated "cholera canals." How to dispose of the sewage, so as to relieve the Danube Canal of the burden of carrying it through the city, is a question still to be solved.

The sewers now built are principally of elliptical form, *i. e.*, with elliptical invert and circular arch. At the end of 1872, the length of public sewers was estimated at only one hundred miles, and the house-sewers about two hundred and eighty miles.

19. SEWERAGE OF THE EXPOSITION.—This was a very complete arrangement, and it required no little skill to overcome, in an economical way, the obstacles presented by the unfavorable situation of the buildings with reference to the outlets available.

The Exposition grounds are only about 3 feet above the ordinary flood-level of the Danube, and the floor of building some 4 feet higher.

Owing to the distance, some 4,000 feet, intervening between the outlet at the point selected, and the grounds, it was not possible to get sufficient fall to give an uninterrupted flow and discharge of the sewage. Such a height was fixed on for the outlet as would admit of a natural discharge during the ordinary stages of water. When the water rose above this stage, pumping was resorted to. The mode adopted was to pass the sewage, near the outlet, through two cisterns sunk below the level of pipe on the line of the main drain. These cisterns were connected together by a pipe on the same level as the outlet-pipe. In the cistern next to the river, a valve was placed over the pipe discharging from the first cistern. When the water rose in the river above the level of this pipe or the outlet, the valve closed and prevented back-water from entering the sewer. A steam-pump was then attached to the first cistern, and the sewage pumped over into the second, when it escaped by gravity to the river.

The plan for drainage was worked out carefully in every detail, showing position, size, and grade of pipe, and quantities. There were some eighty isolated buildings to drain, besides the main building. Mr. John Phillips, an English engineer, had this work in charge.

The sewers were built small to prevent the accumulation of gas. Making provision for the removal of the storm-water falling on the grounds seemed to form no part of the system. On two or three occasions the walks and depressed portions of the grounds about some of the pavilions were badly flooded.

20. SEWERAGE OF HAMBURG.—The Hamburg building-deputation exhibited models and plans relating to the sewerage of that city, showing the mode of construction, arrangements for disposing of the sewage, and appliances for flushing sewers or producing artificial currents, where sufficient fall could not be obtained to carry off the sewage by natural flow. The gates or valves were made, in many cases, to work automatically or by force of water from the city water-supply. There was nothing especially new in this direction, the appliances being in general conformable to English practice.

21. FRENCH HYDRAULIC ENGINEERING.—The French ministry of public works made a fine exhibit of charts, plans, and models appertaining to the water-works and sewerage of Paris and the public works of France. Their exhibit included two publications, *Notices sur Les Dessins Modeles etc relatifs aux travaux des ponts et chaussees et des mines Exposés a Vienne* and *Etude Historique et Statistique sur les voies De Communication de la France*, containing the history, statistics, and an account of the working of these improvements.

22. INTERNAL NAVIGATION.—Their system of internal navigation was profusely illustrated and gave a good opportunity for the study of this branch. Until recently a large part of their navigation, especially on the Yonne and the Upper Seine, had been intermittent and very unsatisfactory, although large sums had been expended annually in improv-

ing these rivers. By the general adoption of movable dams, models of which were exhibited, the character of the navigation was radically changed.

The latest improvement in movable dams was represented in a working model, showing modification of a Girard shutter-dam, worked by hydraulic pressure. The description, as given in the first volume referred to, is as follows: "This system comprises: First, a series of great wooden water-gates, movable around a horizontal axis working in a cast-iron shoe secured to the floor of the dam. Second, hydraulic presses applied on the down-river side of the floor, solidly anchored in the masonry and destined to work the gates. The piston of each press bears a cast-iron cross-head working in slides. To this cross-head three rods are attached to communicate the pressure to a cross-bar fastened in the center of the movable gate. Third, a series of copper tubes which put each press in communication with the generator or reservoir of power destined to transmit water under the pressure of the hydraulic presses. Fourth, hydraulic works built on the abutment of the dam. These comprise a turbine with a vertical axis, and a double force-pump which receives motion from the turbine, and a reservoir of force. The pumps and the reservoir communicate with each other and with the presses by means of three-way cocks which let the water either into the reservoir or into the presses or empty it into a discharging-tube. The maneuvering of the gates is effected by simply moving these cocks. By putting in communication each press, either with the pumps or with the reservoir of power under a sufficient pressure, an ascending motion of the piston is effected, and, in consequence, the gate rises. By opening the cock into the waste-pipe the water escapes under pressure of the gate, the *corps de presse* is emptied, and the gate sinks. The reservoir force is a regulator of the play of the pumps; it moreover permits the dam to be raised when sufficient height has not been attained by the water to put the turbine in motion. The weir of the dam Îsle Brulé is 82.5 feet in length; the sole is 6½ feet below the level of the upper pool. The gates are seven in number, with a press for each shutter, and have a length of 11.5 feet and a height of 6½ feet. When raised they show a total batter of 16 inches; when down they lie horizontally on the crown of the sole."

23. MOVABLE WEIRS.—Another model exhibited an arrangement of movable shutters supported on points near the middle of their heights instead of at the bottom, working in wrought-iron frames revolving on a horizontal axis on the sole of the dam as the shutters in the first case. The shutters are held in place by props on the down-stream side, (one for each shutter,) running in cast-iron ground plates placed in the direction of the thread of the stream on the floor. Each plate has a notch to catch the foot of the prop in to hold the shutters up to place. The props are tripped by a rod running along the floor from either shore,

with bosses on it at the proper intervals to catch the feet of the props and knock them out of the notches. The shutters fall down-stream by the frame turning on its axis, carrying the shutter back and dropping it in a horizontal position on the floor, the foot of the shutter corresponding to the line of the axis of rotation of frames. To raise these shutters, wrought-iron trestles are fixed at intervals to the floor on the up-river side of the dam, with feet hinged so as to allow the trestles to revolve at right angles to the direction of the dam-crest. When the shutters are down the trestles fall into a recess on the river-bed. On these trestles a movable bridge is formed by wrought-iron stringers, with a wooden platform swung to them. These stringers carry a truck with a windlass, which works a chain attached to the foot of the shutters, drawing them forward, and at the same time raising them by causing the frame to which the shutters are attached to turn on its axis in the sole. The shutter, by this means, is kept nearly horizontal while raising the frame; after this is done and the prop drops into the notch, the shutter is tipped and is seated by the force of the current. This style of shutter is used in the navigable passes of the dams.

24. THE YONNE AND THE SEINE.—After leaving the Exhibition, on the return trip, by a diversion of the route, the writer took in the Yonne and Seine Valleys between Laroche and Paris, in order to get a glimpse ot these improvements.

These rivers are small in comparison with those of America. They traverse a highly-improved section of country. The margins of the rivers resemble the artificial water-lines of great parks, so clean, well-kept, and perfectly protected are they. There is no waste, no rubbish, or drift, to offend the eye or interfere with navigation.

Between Laroche and Paris, a distance of some one hundred and thirty miles, no less than thirty-five dams intervene. These pool the rivers, generally, to the depth of 5 and 6 feet.

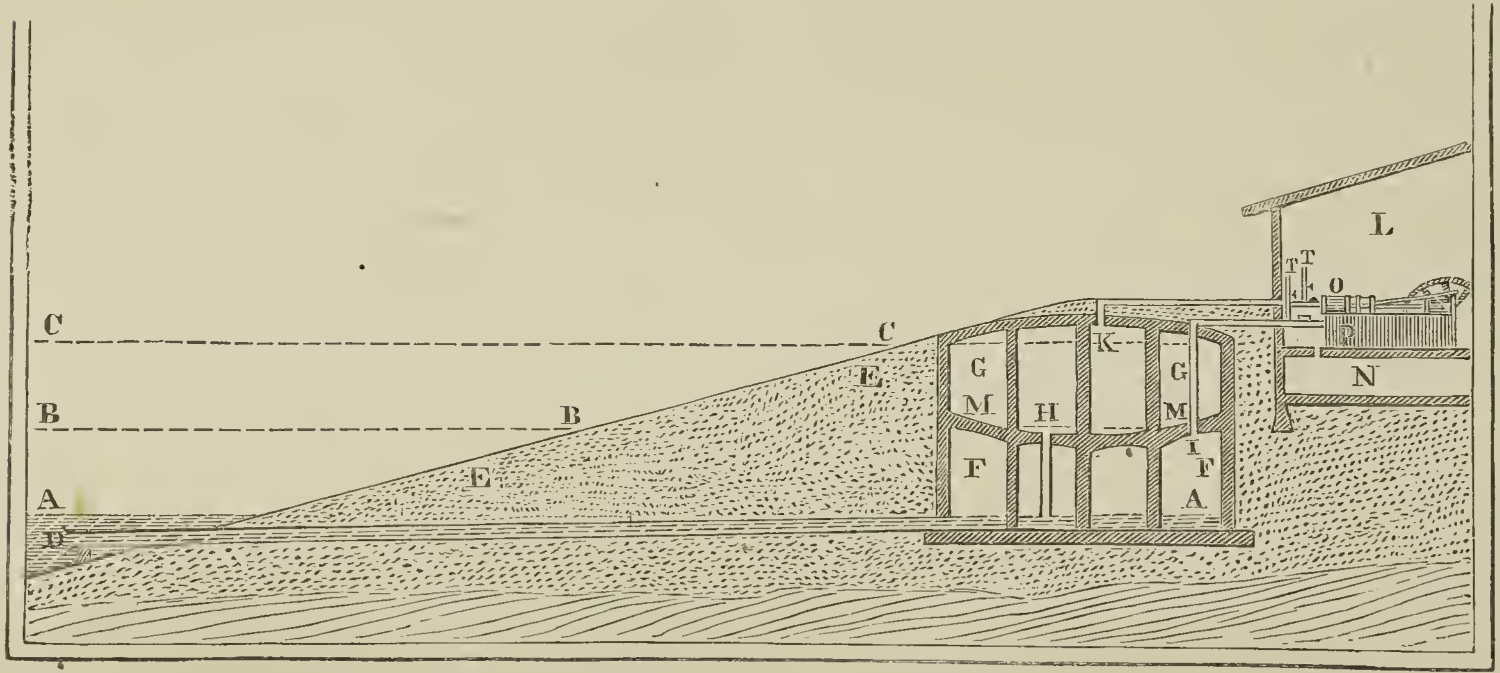
The dams are provided with an opening of from 150 to 200 feet wide, and of full depth, and a weir or overfall from 200 to 300 feet in length, having its crest from 2 to 3 feet above the bottom of the channel. A heavy masonry pier separates the two parts. Next to the shore a lock is placed to be used in low water.

25. TIDE-MOTORS.—F. Tommassi, of Paris, exhibited by a working model, on a large scale, a novel mode of utilizing the tides. Plate 3 shows the arrangement, and, to use his own specification, it consists in a reservoir acting as a boiler, and a moving apparatus acting as an engine. The top of the reservoir corresponds to high-water line *c c*; line *m m*, corresponding to B B, is the mean level of the sea. When the water reaches the level B, the air contained in the compartment F, finding no outlet either by the tube H, which is submerged, or by the tube I, whose cock is closed, is compressed to a tension proportioned to the weight of the sea-water. By letting the compressed air communicate with the induction-pipe of the engine, the latter is put in motion

TIDE MOTORS.

Plate 3.

Section representing the sea, the shore, and the reservoir.



A A represents the mean low-water line at spring-tides.
C C represents the mean high-water line at spring tides.
B B represents the mean level of the sea.
D represents the tube which connects the sea and the reservoir.
E represents the reservoir.
F represents the lower division.
G represents the upper division.
H represents the tube which connects the sea with the upper department.
I represents the tube connecting the lower division with the admitting-tube to the moving apparatus.
K represents the tube connecting the lower division with the discharging-tube of the moving apparatus.
L represents machine.
M represents horizontal dividing-line.
N represents underground of machine.
O represents the cylinder, with piston of the moving apparatus.
P represents the pump to compress air.

VIENNA INTERNATIONAL EXHIBITION. 1873.

Sewer under the Via Romagnosi in Milan.

Fig. 3

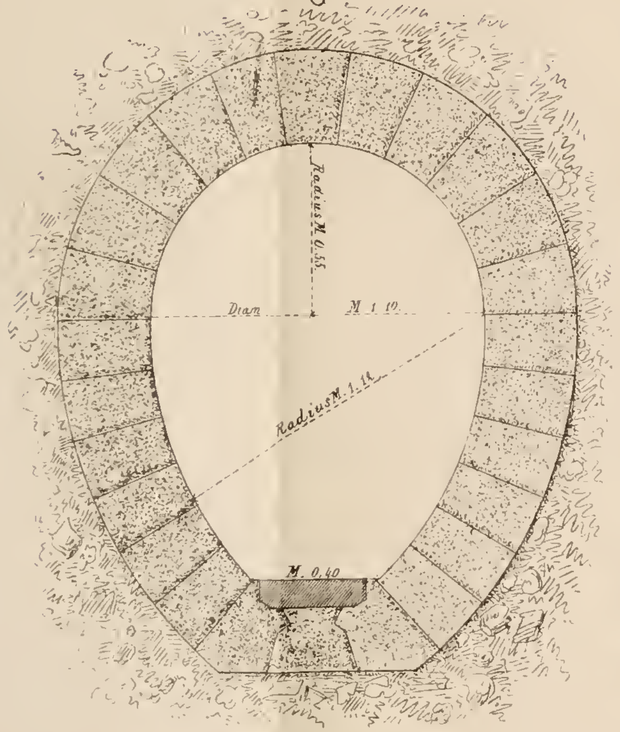


Fig 4

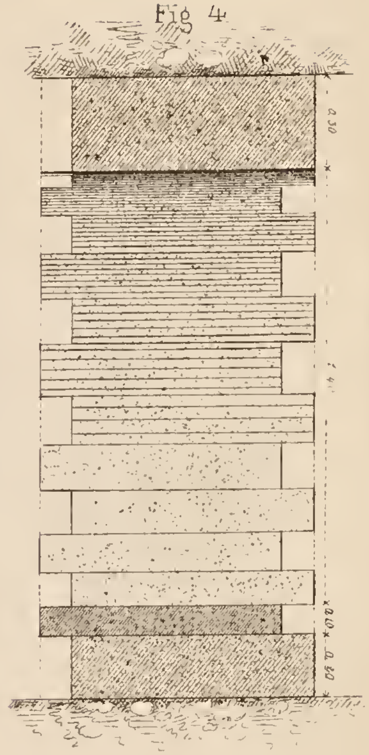


Fig 5

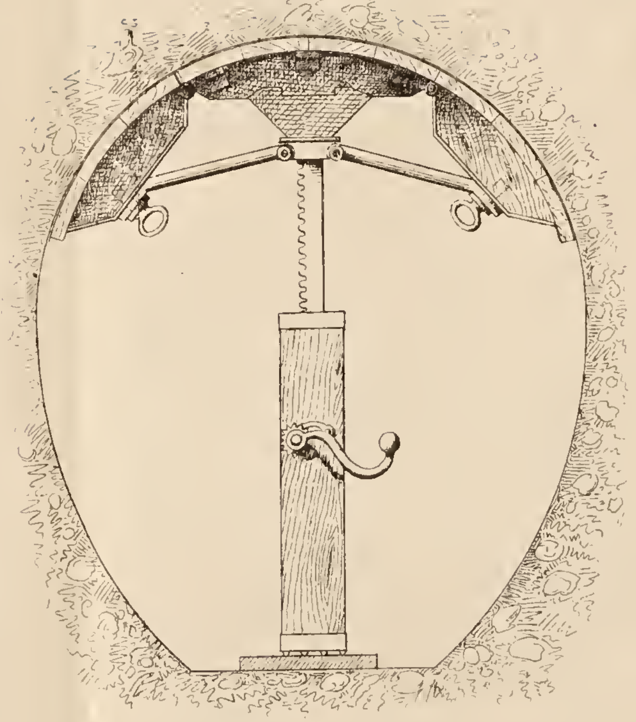


Fig 6

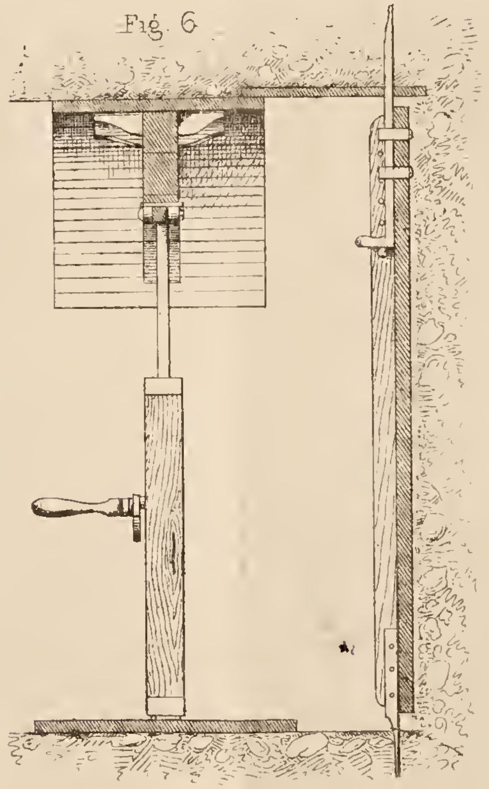


Fig 7

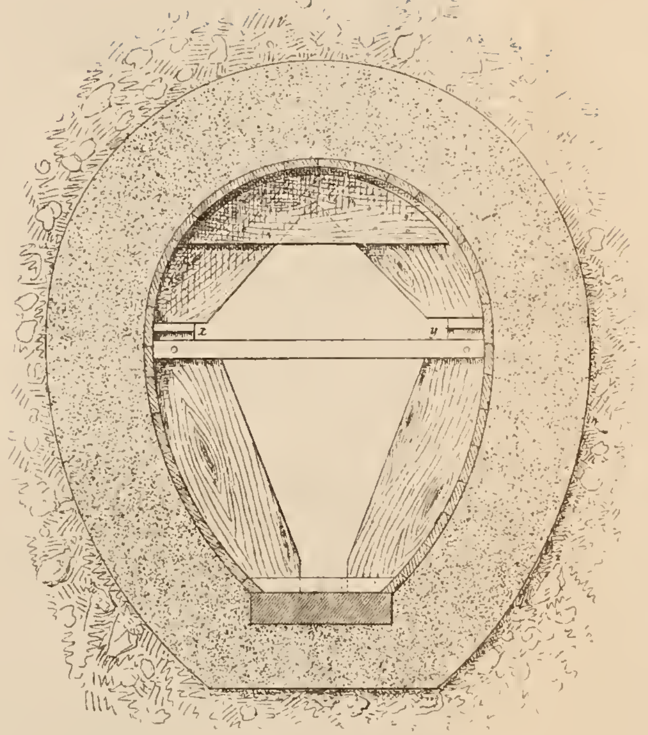
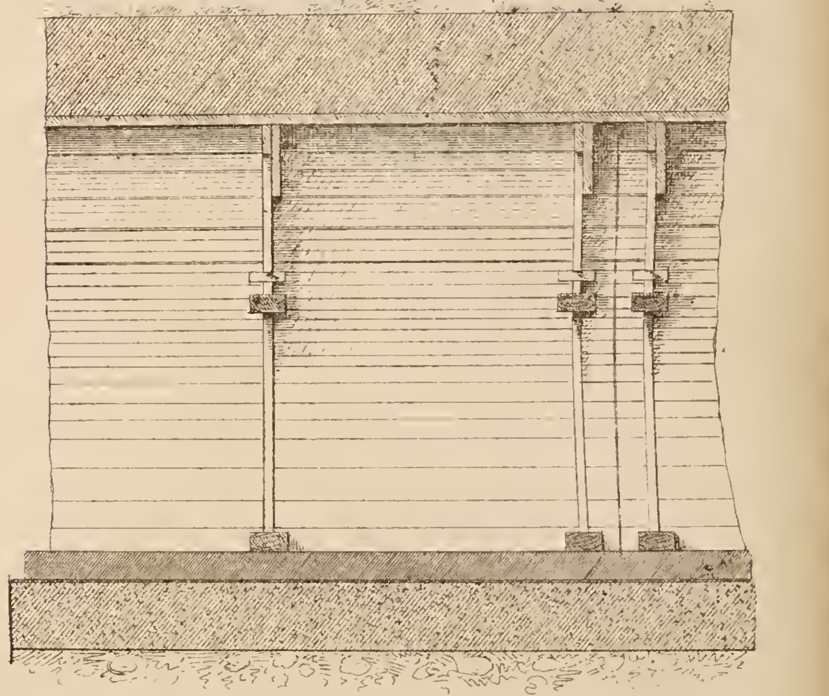


Fig 8



Longitudinal Scale $\frac{1}{400}$ *for Fig 1.*

Vertical Scale $\frac{1}{200}$ *for Fig 1*a

Scale $\frac{1}{20}$

Fig 1.

Base line at 1 Meter above the soglia of the principal door of the Duoma and 123.131 Meters above the level of the Sea.

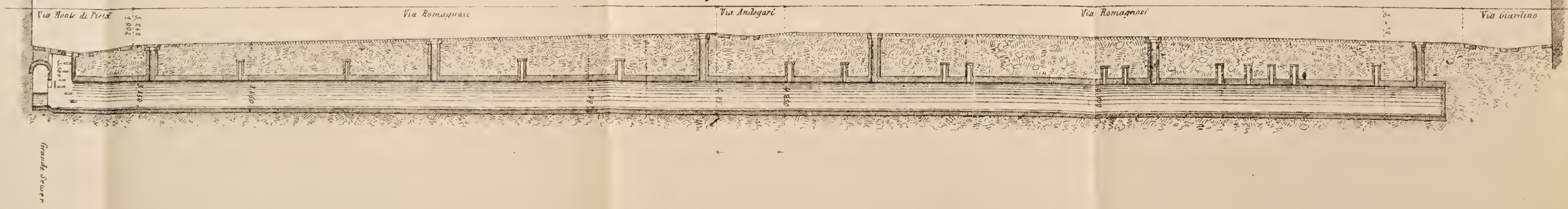
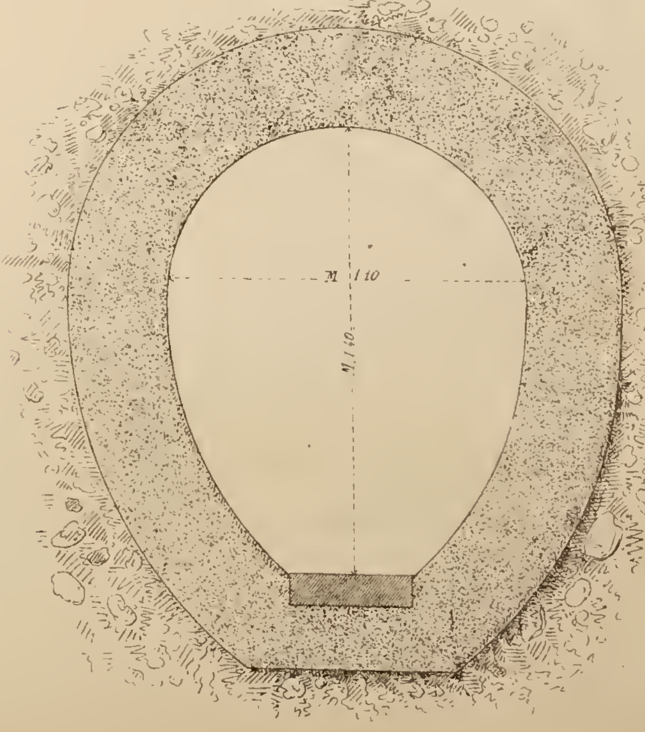


Fig. 2



and so continues to the end of the flood, about three hours. During this time, the water entering freely by the tube H, in compartment G, (the pipe K being in communication with the atmosphere,) fills the compartment to the height of the flood. Closing now the cock of tube K, the water which fills the compartment G is prevented from escaping. When the tide recedes to point B, the weight of the water in compartment G, falling, rarefies the air inclosed between the water and the moving apparatus. The result is, when the induction-pipe of the apparatus is put in communication with the atmosphere, and the eduction-pipe with the pipe K, that the atmosphere will press on the pistion with a force depending on the degree of rarefaction attained, producing an effect the reverse of the first operation, and lasting about the same time. The model worked well, but its practical application, in its present shape, would no doubt be attended by many difficulties, both in the way of expense and in getting the proper construction.

26. BRIDGE AT BUDA-PESTH.—The *Société de construction des Batignolles, E. Gouin, ingénieur a Paris*, exhibited the design of the bridge across the Danube at Buda-Pesth, in a very elaborately-worked model, giving the particulars and details of construction. The bridge is a cast-iron arch of five spans, the principal one 300 feet in the clear. The model was some 10 feet long, and was arranged to show the river-bed, pier-foundations, and water; or, in other words, to give a miniature representation of the structure as it (or a portion of it at least) appears in place. The bridge crosses the river just below Margaretta Island, situated in the middle of the river, and constituting the fashionable summer-resort of the two cities. The bridge connects with this island, and is built in two arms, these arms meeting in the river at a point below the island, and some distance above the abutments. From the point of juncture of the two arms, a short viaduct leads to the island, and gives the bridge three approaches or portals. This is an arrangement somewhat similar to the bridge over the Rhone at Geneva.

27. ITALIAN ENGINEERING.—In the Italian department the engineering-section was well represented in models and plans of their principal works, principally irrigation-work.

Plans of the Cavour Canal for conveying water and improving the grounds in the lowlands between Verona and Orfigli, and works of a similar character for irrigation in the vicinity of Naples. The models were for aqueducts, siphons, sluice-houses, &c. As this related to a specialty not likely to receive much consideration with us for some time to come, very little attention was given to it, farther than to note some points on construction.

Brick is the material in general use for these works. Concrete is also largely used, especially in the auxiliary works, conduits, and syphons; the mode of construction with this material is illustrated in Plate 2, representing a sewer canal under the via Romagnosi, Milan, and built by Emelia Bignani, engineer of Milan, in 1869. In 1870–'72, several similar works were executed there. These egg-shaped sewers are built as large as 6.6 feet vertical diameter. This plan of tunnel-construction is adapted for sewers under streets carrying a heavy traffic, so as to avoid the interference that would otherwise occur with open trenches. The tunnel is excavated to the shape of the outside section required. The arch is sustained by lagging, held to place by jacks with three arms, as shown by Figures 5 and 6. The bottom is brought to shape with concrete and capped with a granite stone invert; on this a wooden core rests, (Figure 7,) some 20 feet long, built in sections of about 5 feet, and divided into two parts at the springing-line and adjusted by wedges, so as to facilitate removal. Around this core the concrete, composed of three parts clean gravel, two parts sand, and one part of Portland cement, is filled and rammed; the core is moved forward as the work advances piece by piece. The cores are allowed to set forty-eight hours, and sometimes four or five days, according to the weather. Concrete is largely used in Germany and Austria for engineering works and buildings generally.

28. Engineering exhibits from the United States.—In the American department the most interesting exhibits were those presented by the Louisville Bridge Company, Kentucky, and by the War Department. The former was represented by a well-executed model of the great railroad bridge over the Ohio River at Louisville. This structure is 5,219 feet long, and is divided into twenty-seven spans of varying lengths of from 150 feet to 400 feet. The large span is placed over the main channel, and has its floor-level 101 feet above low water. A second channel is spanned by a 370-foot truss. The style of construction is Fink's suspended truss, except for channel-spans, where Fink's triangular truss is used.

The War Department, through General Newton, engineer in charge of the Government-works at New York Harbor, exhibited a plaster model of excavations at Hell-Gate, East River. This, in connection with the circular accompanying it, served to illustrate thoroughly the character and magnitude of the operations connected with the removal of this reef. It appears that since the commencement of the work in 1869, the tunnels and galleries, shown in the model, ten of each, amounting to 4,716 feet, have been excavated, in addition to the work of sinking the shaft, and of constructing the coffer-dam to protect its mouth; and, further, that the works for the complete demolition of this dangerous obstruction are about completed. The portion of the reef jutting out into the channel, about 300 feet, prevented anything being done immediately over it, and the only practical resource left was to sink a shaft on the shore in such a position that its mouth with reference to the water-levels could be protected by a coffer-dam, and drive headings by radial lines through this mass of hard gneiss rock to its outer edge, and to connect these by concentric cross-galleries. The lay of the rock permitted the grade of the headings to fall back to the shaft, where the drainage is effected by pumps. The estimated quantity of rock to be removed in reducing this ledge to the level required for safe navigation, viz, 26 feet below low water, is 50,584 cubic yards. The area embraced in this work is about three acres. The ridge of the ledge, for a great part of the distance, is only 12 feet below low water. The blasting is done with nitro-glycerine, using small charges (8 ounces only) for fear of injury to the roof of the tunnels. The holes were drilled principally by percussion and diamond drills, operated by compressed air. Some 20,000 charges have been fired. When the tunnels are carried out as far toward the extremities of the rock as the water will admit, and the piers between them and the cross-galleries have been reduced to the minimum size consistent with stability, the whole is to be blown up, and the *débris* leveled down on the ruins.

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